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OF
THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

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The Society as a body is not responsible for the statements of facts or opinions advanced in papers or discussions. C 55

THE JOURNAL

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 32 FEBRUARY 1910 NUMBER 2

THE New York monthly meeting for February will be devoted to the dedication of a bronze memorial tablet to Dr. Robert H. Thurston, the first president of The American Society of Mechanical Engineers. All associates and former students of Dr. Thurston are earnestly invited to attend these exercises to show their esteem for him as a friend and in recognition of his brilliant career as an engineer and educator.

Addresses will be given upon Dr. Thurston as a man, and his life work, by speakers of wide reputation who knew him intimately. These addresses will touch upon his experience as an engineer of the navy during the Civil War; his work as an educator at Stevens Institute of Technology and at Cornell University; his achievements as engineer and investigator; as an author; and his long relationship with The American Society of Mechanical Engineers.

Among those who will participate are Prof. John E. Sweet, closely associated with Dr. Thurston in the organization of the Society; Col. E. A. Stevens, the prominent representative of the Stevens family, founders of Stevens Institute; President J. G. Schurman of Cornell University; and Mr. William Kent, consulting engineer. Dr. Alex. C. Humphreys, president of Stevens Instutite, will be the chairman.

The beautiful memorial which is to be unveiled is the work of Herman H. McNeil, a former student and personal friend of Dr. Thurston. It is a replica of the memorial tablet presented to Sibley College, Cornell University, by alumni and students of the university. The tablet was placed in the rooms of the Society through the gener-

osity of members and their devotion of Dr. Thurston. Contributions were received by a committee consisting of John Fritz, S. W. Baldwin, Prof. R. C. Carpenter, W. C. Kerr, E. A. Uehling, Wm. Hewitt, and Gus C. Henning. The installation of the memorial and the arrangement for the dedicatory exercises were made by a committee consisting of Dr. Alex. C. Humphreys, *Chairman*, and Messrs. Chas. Wallace Hunt, Fred J. Miller, Prof. R. C. Carpenter and J. W. Lieb, Jr.

MEETING IN BOSTON, FEBRUARY 16

There will be a meeting of engineers in Boston on February 16 conducted by the American Institute of Electrical Engineers with the coöperation of The American Society of Mechanical Engineers and the Boston Society of Civil Engineers. The meeting will be held in the auditorium of the Boston City Club, 9 Beacon St. The subject of the meeting is Industrial Power, arranged for by the Industrial Power Committee of the American Institute of Electrical Engineers. Five papers will be presented, the authors being Prof. D. C. Jackson, Mem. Am. Soc. M. E., Charles T. Main, Mem. Am. Soc. M. E., Robt. S. Hale, Mem. Am. Soc. M. E., Geo. H. Stickney and W. B. Nye.

SPRING MEETING, ATLANTIC CITY, MAY 31–JUNE 3

The Spring Meeting of The American Society of Mechanical Engineers will be held this year as usual, in addition to the London Meeting which occurs in July. Atlantic City, N. J., has been selected by the Meetings Committee and approved by the Council as the place, and the meeting will be held from May 31–June 3 inclusive. The headquarters during the meeting will be at Hotel Marlborough-Blenheim.

NEW YORK MEETING, JANUARY 11

The New York monthly meeting for January drew out a profitable discussion on lubrication. The Society was fortunate in having for its guests Dr. C. F. Mabery, Professor of Chemistry at Case School, Cleveland and Dr. P. H. Conradson, chief chemist of the Galena-Signal Oil Company, Franklin, Pa. Dr. Mabery presented a paper, published in this number of The Journal, on Lubrication and Lubricants. The paper deals largely with laboratory tests in the performance of which Dr. Mabery has been signally successful and from which

he has deduced interesting results both withoils alone, and with oil and graphite and water and graphite.

Following Dr. Mabery's address, a paper by Prof. F. H. Sibley upon Efficiency Tests of Lubricating Oils, published in The Journal for November, was read by Dr. Charles E. Lucke. The discussion was lead by Dr. Conradson, who sought to show the extent to which laboratory practice might be expected to have a bearing on the performance of lubricants in actual practice and explained certain practical considerations that must be taken into account in the lubrication of different types of machinery. Others who contributed to the discussion were William M. Davis of Boston, Henry Souther of Hartford, Conn., F. R. Low. Dr. D. S. Jacobus, C. A. Hague, and George A. Orrok of New York.

MEETING OF THE COUNCIL

A meeting of the Council was held Tuesday, January 11, in the rooms of the Society. There were present, Charles Whiting Baker, Prof. R. C. Carpenter, George M. Bond, Charles Wallace Hunt, Dr. Alex. C. Humphreys, James Hartness, Prof. F. R. Hutton, I. E. Moultrop, Col. E. D. Meier, Jesse M. Smith, F. W. Taylor and H. G. Stott, and the Secretary. In the absence of the President, Dr. Humphreys was chosen Chairman.

The minutes of the meeting of December 10 were read and approved. The Secretary announced the following appointments by the President: Executive Committee, Dr. Alex. C. Humphreys, *Chairman*, Charles Whiting Baker, *Vice-Chairman*, H. L. Gantt, Prof. F. R. Hutton, F. M. Whyte; Standing Committees: Finance, A. M. Waitt, reappointed; House, H. R. Cobleigh; Library, Alfred Noble; Meetings, Willis E. Hall, reappointed; Membership, Theodore Stebbins; Publication, Geo. M. Basford; Research, James Christie, reappointed, and in place of Dr. Charles B. Dudley, deceased, Ralph D. Mershon.

Voted: To confirm the Executive Committee as named.

The resignations of Carl S. Dow, W. A. McFarland and R. Raymond were accepted.

Voted: To approve the action of the Meetings Committee in the appointment of the following sub-committees: on Sugar Machinery, H. deB. Parsons, Thos. F. Rowland and Dr. D. S. Jacobus; on Machine Shop Practice, L. R. Pomeroy, Prof. Walter Rautenstrauch and John Parker Illsley.

Voted: That the resignations of the Committee on Power House Piping be accepted.

Voted: To accept the invitation of the National Civic Federation to this Society, to be represented at the conference in Washington, January 17–19. In accordance with a vote of the Council, the Chairman appointed the following Honorary Vice-Presidents: Jesse M. Smith, Past-President, Chas. Kirchhoff, A. W. Burchard, E. G. Spilsbury, F. M. Whyte and Wm. H. Wiley.

Voted: To accept the resignations of the Committee on Land and Building Fund, in accordance with the request of the committee.

Voted: That the Executive Committee be requested to nominate to the Council a committee of three or more to take up this work; and that such recommendation be presented at the next meeting of the Council.

In accordance with previous discussion by the Council the following amendments were formally approved:

B 23 The Finance Committee shall consist of five Members or Associates The term of office of one member of the Committee shall expire at the end of each Annual Meeting. This committee shall, under the direction of the Council, have a supervision of the financial affairs of the Society, including the books of account. The Committee may cause the accounts of the Society to be audited and approved annually by a chartered or other competent public accountant. The committee shall hold monthly meetings for the audit of bills and such other business as shall come before it and shall deliver to the Secretary for presentation to the Council at the end of each fiscal year, a report of the financial condition of the Society for the past year, and also shall present therewith a detailed estimate for the probable income and expenditure of the Society for the following twelve months. It shall make recommendations to the Council as to investments, and, when called upon by the Council, advise upon financial questions. It shall have charge of the making of all contracts and other obligations to pay money in the Society's work and the ordering of all expenditures thereunder.

B 25 The Publication Committee shall consist of five Members or Associates. The term of office of one member shall expire at the end of each Annual Meeting. The Committee shall review all papers and discussions which have been presented at the meetings, and shall decide what papers or discussions, or parts of the same shall be printed in the Transactions of the Society. The Committee shall have the supervision of the monthly publication of the Society known as "The Journal." The Committee will be expected to publish all such data as will be of assistance to engineers or investigators in their work. At the end of each fiscal year the Committee shall deliver to the Secretary for presentation to the Council, a detailed report of its work.

On behalf of the Executive Committee, Charles Whiting Baker reported that the S. S. Celtic, sailing July 16, had been selected as the

vessel on which the main party attending the Joint Meeting in England would cross.

I. E. Moultrop, Chairman of the Committee on Meetings of the Society in Boston, reported regarding the joint meeting with the American Institute of Electrical Engineers and Boston Society of Civil Engineers, to be held January 21, and presented in the name of his committee an invitation to members of the Council to be present.

On motion the meeting adjourned to February 8.

JOINT MEETING WITH THE INSTITUTION OF MECHANICAL ENGINEERS, BIRMINGHAM, ENGLAND, JULY 26-29, 1910

The Society has selected as the official steamer for the members and their families, *the mammoth twin-screw S. S. Celtic of the White Star Line*, which is scheduled to sail from *New York, Saturday, July 16, 1910, at 2 p.m. for Liverpool*, calling en route at Queenstown and Holyhead.

In order that we may retain our option of the *entire first-class accommodations of the Celtic*, it is necessary that all arrange to sail on this steamer.

THE OFFICIAL STEAMSHIP

The Celtic, 20,904 tons, ranks among the largest steamers in the world. Because of her exceptional steadiness and the general roominess of her staterooms and the public apartments, she is one of the most desirable of Atlantic steamers.

There is a large variety of passenger accommodations, among them several promenade and upper promenade suites, consisting of bedrooms and sitting rooms, with private bath and toilet rooms. A limited number of single staterooms, for the sole occupancy of one passenger, may be had; and there are numerous outside and inside cabins at various prices. The four promenade decks present unexcelled opportunities for rest in a steamer chair or exercise and games on deck.

The Celtic is fitted with Marconi wireless, submarine signaling apparatus and other modern safety devices.

SPECIAL RATES

From the regular tariff rates of the Celtic, the Committee has secured for our members a reduction of ten per cent, except when such a rebate would cause the price to fall below $97.50, the fixed minimum rate. For example, the rate for room 117 is $300 when occupied by two persons; but with the 10 per cent rebate the price will be $270 for two, or $135 each.

EARLY DECISION ESSENTIAL

As our option upon the Celtic's accommodations is necessarily limited because of the great pressure from the general public to leave America on this popular ship and date, all who decide to sail should communicate promptly with the *White Star Line, 9 Broadway, New York,* where all correspondence should be sent. The decision must be made before February 15.

HOTEL AND RAIL ARRANGEMENTS

The meetings will begin in Birmingham on Tuesday, July 26, and complete arrangements will be made for landing the entire party, Sunday, July 24, in Liverpool, and conveyance to and reservations in a hotel in that place. Monday will be spent in Liverpool; on Tuesday morning, the party will be conveyed by a special train to Birmingham and located in hotels in the latter city.

SIDE TRIPS

Side trips in England, on the Continent, or to any part of the world, can be arranged through the White Star Line, which will gladly reply to all inquiries. If members will immediately indicate their preferences in this matter, the White Star Line will act as a clearing house to bring together those who may have similar intentions.

THE RETURN TRIP

As the rush of return travel from Europe to America always taxes all available passenger accommodations between August 15 and September 25, members are strongly advised to secure round trip tickets now. For those who desire to return by any of the following lines, namely, White Star Line, American Line, White Star-Dominion, Atlantic Transport, Leyland and Red Star Line, the International Mercantile Marine Company (which controls them) is prepared now to make reservations *at regular rates.* The sailing dates of the various steamers will be furnished on application to the White Star Line. The bookings for European travel are the heaviest in history, and failure to reserve return passage immediately may result in serious inconvenience. Should members desire to return by other lines, the return tickets are interchangeable, but the necessity to reserve accommodations now is imperative in any case.

As the Society is the guest of the Institution of Mechanical Engineers, it will be impossible to include in the party gentlemen guests. The invitation which the Society accepted is extended only to the members and their immediate families.

On the last page will be found a list of members who have already signified their intention to attend.

Correspondence regarding the outgoing passage, reservations, side trips, etc., should properly be conducted direct with the White Star Line, 9 Broadway, New York. On the other hand the committee will be pleased to answer any communications.

ALEX. C. HUMPHREYS, *Chairman*
CHARLES WHITING BAKER, *Vice Chairman*
H. L. GANTT
F. R. HUTTON
F. M. WHYTE
} Executive Committee

CALVIN W. RICE, *Secretary.*

ATTENDANCE AT THE JOINT MEETING

The following members, accompanied by 137 ladies, have signified their intention to attend:

The President

GEORGE WESTINGHOUSE

Past-Presidents

PROF. F. R. HUTTON, *Honorary Secretary* OBERLIN SMITH JESSE M. SMITH
AMBROSE SWASEY F. W. TAYLOR WORCESTER R. WARNER

Vice-Presidents

W. F. M. GOSS COL. E. E. MEIER F. M. WHYTE

Managers

H. L. GANTT JAMES HARTNESS

Treasurer — WILLIAM H. WILEY
Chairman Membership Committee — WILLIS E. HALL
Secretary — CALVIN W. RICE

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C. J. Angstrom	Charles L. Bauer	J. H. Bloomberg
G. Ayres	Laurence V. Benet	Robert W. Boenig
Abram T. Baldwin	Wm. P. Bettendorf	R. P. Bolton
C. Kemble Baldwin	Sydney Bevin	Wm T. Bonner

George A. Boyden
Geo. M. Brill
Morgan Brooks
John Calder
Henry W. Carter
David A. Chapman
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A. W. Colwell
Jas. V. V. Colwell
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F. W. Dean
D. de Lancey
James B. Dillard
Henry B. Dirks
W. F. Dixon
William T. Donnelly
Walter C. Durfee
H. Emerson
Q. N. Evans
Thomas M. Eynon
John P. Faber
A. D. Finley
H. D. Fisher
F. A. Flather
B. P. Flint
E. H. Foster
William Fox
Harry C. Francis
Lawford H. Fry
R. W. Fuller
Francis E. Galloupe
E. A. Garratt
William Gleason
F. A. Goetze
Geo. E. Hallenbeck
Chester B. Hamilton, Jr.
J. A. Herrick
Henry Hess
C. P. Higgins
M. P. Higgins
E. L. Hill
Thos. Hill
Lewis G. Howlett
Leigh A. Hunt
Dugald C. Jackson
E. L. Jahncke
Herman G. Jakobsson
E. H. Jewett
William J. Keep
L. H. Kenney
J. G. Kingsbury
Charles Kirchhoff
Frank B. Klock
G. L. Kothny
H. M. Lane
Nisbet Latta
R. K. LeBlond
Wilfred Lewis
J. H. Libbey
Wm. Lodge
Charles Longstreth
F. R. Low
Robert T. Lozier
Walter MacGregor
H. B. MacFarland
J. Macfarland
Robert A. McKee
James W. McLaughlin
Charles T. Main
A. K. Mansfield
Thos. Marrin
W. C. Marshall
R. E. Mathot
A. V. Matlack
Geo. Mesta
E. W. Mix
W. O. Moody
Robert C. Monteagle
L. H. Morgan
R. L. Morgan
James W. Nelson
Charles Z. Newell
J. G. O'Neil
Geo. A. Orrok
Henry S. Otto
Wm. F. Parish, Jr.
F. A. Park
J. C. Parker
F. A. Parkhurst
Charles H. Parson
C. D. Pettis
H. Hobart Porter
Jos. G. Prosser
Thos. C. Pulman
L. S. Randolph
E. Howard Reed
Joseph Reid
Julian Richmond
Addison A. Righter
J. M. Robinson
J. W. Roe
W. F. Rogers
Axel Sahlin
E. K. Sancton
Thomas H. Savery
C. H. Schlachter
Geo. Schuhmann
Arthur C. Scott
Alonzo B. See
E. C. Sickles
C. C. Simpson
Alton L. Smith
A. Parker Smith
Gubert S. Smith
H. F. Smith
F. H. Stillman
C. W. Stone
E. B. Stone
K. J. Sunstrom
H. H. Suplee
Frank H. Taylor
J. T. Taylor
F. W. Teele
B. L. Thompson
F. Thuman
Edw. D. Thurston, Jr.
John T. Tiplady
F. E. Town
H. P. Townsend
G. R. Tuska
Willard C. Tyler
John W. Upp
T. A. Van Der Willigen
Edward Van Winkle
P. V. Vernon
F. L. O. Wadsworth
Charles Wald
Adolph O. Wallichs
William Watson
H. H. Westinghouse
William Wilke
F. O. Willhofft
C. N. Wills
Robert York

ENGINEERS' DINNER AT BOSTON

On Friday evening, January 21, upwards of 425 engineers, representative of the engineering profession as a whole, attended the dinner at the Hotel Somerset, Boston, given by The American Society of Mechanical Engineers, the Boston Society of Civil Engineers, and the Boston branch of the American Institute of Electrical Engineers to the presidents of these societies, George Westinghouse, George B. Francis and L. B. Stillwell; to John A. Benzel, president of the American Society of Civil Engineers and other distinguished guests. While the attendance was mainly from Boston and vicinity, there was a large representation from New York and a considerable number from other cities. This was the largest and most enthusiastic meeting that the Boston engineers have held and it emphasized in an unmistakable way the cordial relations existing between the different branches of the profession and the earnest desire for coöperation. There were present eight presidents of engineering societies or institutions, besides prominent members of many others, including architectural and scientific societies closely identified with the work of engineers. The following is the list of guests and others seated at the head table at the dinner:

C. B. Edwards, chief engineer, Fore River Ship and Engine Building Co.; Arthur Warren; Asa M. Mattice, manager of works, Walworth Mfg. Co., S; Boston, Mass.; Lieut-Com. O. G. Murrfin of the North Dakota; Prof. C. F. Allen, of the Massachusetts Institute of Technology; G. A. King, president, N. E. Water Works Association; Prof. D. C. Jackson, Massachusetts Institute of Technology; E. A. Engler, president, Worcester Polytechnic Institute; Desmond Fitzgerald, member, Metropolitan Water Committee; John A. Bensel, president, American Society of Civil Engineers; Elihu Thomson; Geo. B. Francis, president, Boston Society of Civil Engineers; Prof. Ira N. Hollis, Harvard University, Chairman Boston Local Com. Am.Soc.M.E.; George Westinghouse, President, Am.Soc.M.E.; Charles Francis Adams; L. B. Stillwell, President, American Institute Electrical Engineers; Prof. Geo. F. Swain, Harvard University; Jesse M. Smith, Past-President, Am.Soc.M.E.; W. D. Wright, president, N. E. Street Railway club; Calvin W. Rice, Secretary, Am.Soc.M.E.; R. Clepston Sturgis, president, Boston Society of Architects; Chas. T. Main, Boston, Mass.; I. E. Moultrop, mechanical engineer, Edison Elec. Ill. Co. of Boston.

Following the dinner, C. B. Edwards, chief engineer of The Fore River Shipbuilding Company, gave a talk, illustrated by lantern slides, on The Main and Auxiliary Machinery of the Blatteship North Dakota. This is the new "Dreadnaught" of the U. S. Navy, turnbine driven of 20,000 tons capacity. Photographs were thrown on the screen of the ship under trial, of the machinery after installation, and many detail drawings were shown of the arrangement of the boilers, machinery and piping.

Prof. Ira N. Hollis of Harvard University, chairman of the committee on meetings of the Society in Boston, acted as toastmaster and referred to an inquiry made when he came to Boston 17 years ago as to why he had removed "to that remote corner of the country where the engineering efforts were but feeble compared with those of the West." He said the criticism was true geographically but that Boston was in fact a great center of engineering, examples of which he instanced. He then introduced the next speaker, Mr. George B. Francis, president of the Boston Society of Civil Engineers, the oldest engineering society in America, which has for some time had under discussion the question of an engineering building and clubhouse.

This matter, said Mr. Francis, has been considered by a committee of the Boston Society of Civil Engineers, but the available funds are not enough to enable this Society to build on its own account. The committee, therefore, considered the possibility of coöperation with other local societies and with local members of the national engineering societies, making the building a headquarters for the city. Within a radius of 15 miles of Boston about 5000 men are engaged in engineering and architecture and the committee has suggested that such a body might well combine and organize a stock company to control a property which should be a home for local engineers and embrace a clubhouse with restaurant, smoking rooms, sleeping rooms and other features. He outlined a plan for carrying out this idea, including provision for revenue. If it becomes evident, he said, that there is a real demand for some of the wealth and standing of Boston sufficient money can be raised to carry out the project.

Mr. John A. Benzel, president of the American Society of Civil Engineers, warmly advocated the plan proposed by Mr. Francis, saying that an engineers' club could be maintained in a dignified form, keeping well within the spirit of the profession, which would not only agreeably fill the needs for companionship, but would widen the horizon of the different members of the profession.

The plan was also approved by R. Clepston Sturgis of the Boston

Society of Architects and L. B. Stillwell, president of the American Institute of Electrical Engineers, who took the occasion also to speak happily of the relations existing between mechanical and electrical engineers and of the need for coöperation; and in his remarks he further paid a tribute to Mr. Westinghouse saying that for 40 years, during which there has been so tremendous a development of industries, he has stood in the very forefront. It has not been a matter of financial results, merely but of a multitude of inventions promoting the comfort of society and protecting it against dangers resulting from new engineering developments.

At the close of the meeting, Prof. D. C. Jackson made a motion, seconded by I. E Moultrop and C. E. Clark, to the effect that a joint committee be appointed to consider the matter of rasing funds and making plans for the erection of an engineering building and clubhouse in Boston.

Following the speech of Mr. Stillwell, Hon. Charles Francis Adams said a few words of appreciation of Mr. Westinghouse, his intimate friend, after which Mr. Westinghouse was introduced and given a very hearty welcome, the audience rising. An abstract of Mr. Westinghouse's remarks is given below.

The committee having charge of this successful event consisted of Prof. Ira N. Hollis, chairman; Prof. Edward F. Miller and J. H. Libbey for the Mechanical Engineers; H. F. Bryant and F. H. Fay for the Boston Society of Civil Engineers and N. J Neall and J. F. Vaughan for the Electrical Engineers.

ADDRESS BY GEORGE WESTINGHOUSE

It seems fitting and logical that we should encourage closer and more intimate relations among all engineering societies, in order that we may benefit from the power and influence which comes from combined efforts, and by working on broad, generous lines cause individual and professional prejudice to give way to that healthful condition of mind so necessary to correct conceptions and actions.

For many years the tendencies have been toward large and powerful railway and industrial combinations and their constant skilful development. The very magnitude of these, with the evil practices so frequently disclosed, has so aroused the public that there is a fixed determination to establish an exacting governmental control of practically all forms of corporation in order that competition may be encouraged and not stifled, but seemingly without due regard to

the real objects in view, viz., the securing of the best public service in all forms; the best foods and goods for our daily needs; the greatest possible comfort to the masses; and as great freedom as possible from those restrictions which hinder rather than promote honest endeavors.

Fortunately there are indications, of which this gathering is one of many, that the great leaders in our affairs (as witness the meetings of the Governors of numerous States now being held in Washington) are alive to the importance of *the regulation of legislation* and the creation of sentiments which will bring business men to their senses.

The engineering societies, by like joint action, have it in their power to do much to better conditions. Probably there is no better way for them to do so than to show, from their knowledge and experience, that *unregulated competition and rivalry in business* have established conditions which have made our costs greater and rendered ideal conditions in industrial engineering matters most difficult of realization.

To make this clear, I need only call attention to the effects of this unregulated competition in one great industry—the electrical—which has grown up in less than twenty-five years. No user of electrical apparatus can fail to appreciate the advantage if when some repair part was needed certain standards had been followed, but it is a lamentable fact that with the single exception of uniform bases for incandescent lamps, there are now practically no standards.

To illustrate the points I have tried to bring to your attention, I quote as follows from a letter on this subject:

> To illustrate the growth in the number of motor ratings required now as compared to the earlier days when sixty ratings sufficed, a summary is given of the motors manufactured by the company with which I am connected. *These figures refer to stationary motors only in sizes up to 200 h.p.* All of these motors are regularly manufactured and no special motors are included.
>
> For direct current, 55 frames are used giving 1600 ratings.
> For alternating current, 80 frames are used giving 1950 ratings.
> Or a total of 135 frames are used giving 3550 ratings.
>
> Practically anyone of these may be furnished in three types: (*a*) shaft horizontal, (*d*) shaft vertical, (*c*) with counter shaft bracket and bearings mounted on the frame. This makes a total of three times 3550, or something over 10,000 different motors available. In spite of this, there is a constant and increasing demand for special motors. In the past year approximately 10,000 estimates have been made on special motors under 200 h.p., even though the greatest effort has been made to divert all inquiries to our regular lines of motors.

Many of these special estimates were necessary because the prospective customer wanted a motor having the same characteristics as a motor offered by some other manufacturer. Our standard motor may have differed in any one of the following characteristics: *a* Horse power or speed rating; *b* Dimensions of base; *c* Overall dimensions; *d* Height from base to center of shaft; *e* Weight; *f* Method of lubrication; *g* Size of shaft; *h* Performance guarantees.

This demand for special apparatus places a heavy burden on the manufacturer. The purchaser also suffers because of increased cost and long deliveries.

Consideration of the above and a general review of the situation leads to the conclusion that the benefits that will result from standardization will more than compensate for the work and expense required in making the necessary changes.

While these particulars relate only to a part of the motors made by one large company, it must not be forgotten that there are half a hundred others manufacturing equivalent lines of motors and that each maker has his own patterns and designs, so that it is safe to say there are fifty or more thousands of needless variations in motors which have added many millions of dollars to the investment already made in installations of electrical machinery.

I have long believed, and have urged upon my associates, for the fourteen years during which the two large electrical companies have had the joint use by a license agreement of several thousands of patents relating to their business, that by coöperation in the development of apparatus, by the use of the same designs, and by the exchange of engineering and manufacturing particulars, there would be evolved the very best of all kinds of electrical machinery and details, and that the products of the two companies could be made interchangeable, not only to the advantage of purchasers and users of electrical apparatus, but also to the advantage of the companies themselves. Other views have prevailed, however, and there has existed an unregulated competition which has made the electrical industry about the poorest of all in the matter of profits.

There are many here who know of the consequences of the adoption of different gages for railways, the final result being a change involving enormous expense to those railways having the disadvantage of having adopted a standard which differed from that of their more powerful neighbors. Unless there be some action in the near future, by those who have the gift of foresight, we shall soon have a like difficult condition to meet, due to the establishing of widely different systems for the electrification of our main railways. It seems certain that a system capable of universal use should be selected in the near future so that an electric locomotive or car of one railway could operate upon all other lines.

By a combined effort of all of the engineering societies, with the financial support of all manufacturers, who would be largely benefited and could well afford to pay in pro rata amounts the expense of a well-equipped and officered bureau of standardization, it seems to me such a bureau could be established, and could work a reform of incalculable value in our present practice, thus forestalling governmental activity in this direction.

The public needs no further incitement to the regulation of such matters by the Government. What is needed is such wise cooperation on the part of the large interests involved, and such fair consideration of the public rights, as may stay further governmental action and finally render it unnecessary.

GENERAL NOTES

LUNCHEON TO CHARLES KIRCHHOFF

Mr. Charles Kirchhoff, Mem.Am.Soc.M.E., recently retired as Editor of The Iron Age after a career of marked success in technical journalism for a period of thirty years, was tendered a luncheon at the Engineers' Club, New York, on Sunday afternoon, January 16, by a large number of engineers and personal friends. Mr. Kirchhoff will take a much deserved rest which will begin with a West Indian cruise; and while the immediate purpose of the gathering was to wish him a pleasurable voyage it was in reality an outward expression of the esteem in which he is held by his many friends and a recognition of his high accomplishments in his chosen field of professional work.

The luncheon was arranged by Philip T. Dodge, president of the Engineers' Club; T. C. Martin, Chairman Executive Committee, Museum of Safety and Sanitation; E. C. Brown, past-president, American Trade Press Association; Joseph Struthers, assistant secretary, American Institute of Mining Engineers: Theodore Dwight, secretary of committee. President Dodge presided at the luncheon.

Mr. Geo. W. Cope, the present editor of the Iron Age, spoke from an association of more than a quarter of a century with Mr. Kirchhoff, paying him a personal tribute and speaking of his quick perception of the bearing of new developments in commercial or technical progress and of his ability to inspire those around him with fresh zeal and interest in their work. He presented to Mr. Kirchhoff from his former associates a French bronze statute by Picault, entitled "La Source du Pactole." A figure typifiying the engineer holding dividers and hammer is pouring from an earthern jar a stream representative of the River of Pactolus, famed for the gold carried in its sands. The bronze was given as emblematical of the effective way in which its recipient, through his profession as engineer and editor, had contributed to the material benefit of those who had come under the influence of his publication in which is recorded the product of his life's work.

Among those who spoke was John Fritz of Bethlehem, Pa., Hon. Mem.Am.Soc.M.E., who, in spite of his advancing years came to

pay his respects. He expressed his high appreciation of the part contributed by Mr. Kirchhoff to the American iron trade. In the 1840's, pig iron production in the United States was less than 300,000 tons. In a recent year 27,000,000 tons was passed and now the country is producing at the rate of 32,000,000 tons a year. As editor of The Iron Age Mr. Kirchhoff had commented on developments in the industry year after year, described the best practice, analyzed the statistics of production, kept all in the industry informed as to the work of mechanical, metallurgical and electrical engineers in this country and abroad.

Many letters of appreciation were received from friends unable to attend. Among those read were letters from Andrew Carnegie, Hon.Mem.Am.Soc.M.E.; Ambrose Swasey, Past-President Am.Soc. M.E.; Chas. Whiting Baker, Vice-President Am.Soc.M.E.; Prof. Henry M. Howe; John Hays Hammond; John W. Lieb, Jr.; Mem. Am.Soc.M.E.; Robt. W. Hunt, Past-President Am.Soc.M.E. and Hon. William H. Wiley, Treasurer Am.Soc.M.E.

The following members of The American Society of Mechanical Engineers were in attendance: Ed. A. Uehling; Henry R. Towne; J. Waldo Smith; C. H. Zehnder; Colin C. Simpson; C. M. Wales; Henry D. Hibbard; F. A. Halsey; Wm. Schwanhausser; H. R. Cobleigh; J. M. Sherrerd; Albert W. Jacobi; W. L. Saunders; E. G. Spilsbury; Jesse M. Smith; W. H. Taylor; W. W. Macon; J. E. Denton; Walter Wood; John Fritz; Calvin W. Rice; H. F. J. Porter; S. S. Webber; Alex. C. Humphreys; Theo. Stebbins; W. H. Fletcher; Col. E. D. Meier; H. H. Suplee; Dr. Richard Moldenke.

WORCESTER ECONOMICS CLUB

At the fortieth annual meeting of the Worcester Economic Club, held January 13, at Worcester, Mass., Calvin W. Rice, Secretary, made an address on the topic of the evening, The Conservation of Natural Resources. He said in part:

> Natural resources are essentially national resources, hence a subject pertaining to our national welfare should enlist the interest of every citizen.
>
> Our natural resources are of two general classes, those capable of renewal, such as forests and those which may not be replenished, such as the minerals. Obviously the intelligent use of the latter is to make them go as far as they will, improving each year as we do in our methods.
>
> We cannot proceed much further now without realizing that in the use of these resources we must recognize that each of us is a member of society, and that, after all, the fundamental problem is that of the individual versus

society. Where the political stops and the ethical begins, unnecessarily complicates the discussion, and I will not attempt it. Suffice to say, the individual may in the long run succeed only as the community succeeds; therefore, these two phases of the question may be considered together.

Mr. Rice was followed by Dr. George F. Swain, Mem.Am.Soc.M.E. professor of civil engineering at Harvard University, who argued that community rights must prevail over individual rights on conservation or the purpose of good government would be defeated. He gave statistics to prove the advantage of centralization of power companies over small companies.

Hon. Harvey N. Shepard represented the Appalachian Mountain Club and plead for conservation of the forests, with particular reference to the White Mountain conservation. He claimed that cutting the forests tended to fill the rivers with silt.

About 275 guests were in attendance at the meeting, which followed a dinner given by the Club.

FUNERAL OF STEPHEN W. BALDWIN

Honorary Vice-Presidents, appointed to represent the Society at the funeral of Stephen W. Baldwin, were George H. Barrus, Prof. I. N. Hollis, Chas. T. Main, I. E. Moultrop, Dr. C. J. H. Woodbury.

STUDENT BRANCHES

The first regular meeting of the recently organized Student Branch of the University of Wisconsin, held January 13, was addressed by Dean Goss of Purdue University. The officers of the Association are Prof. C. C. Thomas, Mem. Am. Soc. M. E., Honorary Chairman; R. N. Trane, Chairman; E. L. Kastler, Vice-Chairman; G. A. Glick, Secretary; J. S. Langwill, Assistant Secretary; R. A. Reudenbusch, Treasurer. A copy of the constitution has been received by the Society and placed on file.

The Stanford Mechanical Engineering Society of Stanford University holds bi-weekly meetings and during the past semester there have been papers on Grounding Devices by J. B. Bubb, The Hydroelectric on the Stanilaus River by E. A. Rogers, The Mechanics of the Aëroplane by Prof. W. F. Durand. Mem. Am. Soc. M. E., and the Electric Locomotive vs. the Steam Locomotive by Prof. S. B. Charters, among others. The officers of the society are Prof. W. F. Durand, Honorary Chairman; E. A. Rogers, President; A. F. Meston, Vice-President; H. C. Warren, Secretary-Treasurer.

OTHER SOCIETIES

AMERICAN SOCIETY OF CIVIL ENGINEERS

The American Society of Civil Engineers held its 57th annual meeting, commencing January 19, 1910, in the Society House in New York. The officers elected for the ensuing year were: President, John A. Bensel, New York; Vice-Presidents, J. T. Fanning, Minneapolis, Minn., Hunter McDonald, Nashville, Tenn.; Treasurer, Joseph M. Knap, New York; Directors, Wm. E. Belknap and Horace Loomis of New York, Geo. A. Kimball, Boston, Percival Roberts, Jr., Mem. Am.Soc.M.E., Philadelphia, Chas. F. Loweth, Chicago, Arthur D. Foote, Grass Valley, Cal.

In addition to the business sessions, the program included excursions to the new terminal station of the Pennsylvania Railroad of New York City and to the Ashokan Reservoir of the Board of Water Supply, New York. On Thursday evening, Walter McCulloh, consulting engineer of the State Water Supply Commission of New York, gave a lecture on the Conservation of the Water Resources of New York State.

AMERICAN INSTITUTE OF MINING ENGINEERS

The spring meeting of the American Institute of Mining Engineers will be held at Pittsburg, Pa., Tuesday March 1 to Saturday March 5 with headquarters at the Hotel Shanley. This will be largely a metallurgical meeting and members of The American Society of Mechanical Engineers will be welcomed to its sessions. Invitation cards may be had upon application to the Secretary of the Institute, at 29 West 39th Street, New York.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

At the meeting of the American Institute of Electrical Engineers on January 14, Prof. W. S. Franklin and Stanley S. Seyfert of Lehigh University presented a paper on The Space Economy of the Single-Phase Series Motor. The annual dinner of the Institute will be

held at the Hotel Astor on Thursday evening, February 24, with Prof. Elihu Thomson, who has been awarded the first Edison Medal, as the guest of honor.

At the December meeting of the Board of Directors of the Institute 74 Associate members were elected and 66 Students enrolled, while in January 88 Associates and 67 Students were received. The 1910 Year Book has just been issued.

INTERNATIONAL ASSOCIATION OF REFRIGERATION

At a meeting of the Council of the International Association of Refrigeration, held in Paris, December 3, 1909, Gardner T. Voorhees, Mem.Am.Soc.M.E., was elected a member of the Council, in place of Thos. S. McPheeter, deceased, to serve until the meeting of the Second International Congress at Vienna.

It was announced that the Vienna Congress would be held in the University Buildings from October 6–11, 1910, enabling the visitors to be present at the hunting and sporting exhibitions.

WESTERN SOCIETY OF ENGINEERS

The annual meeting and dinner of the Western Society of Engineers was held January 12, 1910 at the University of Chicago. Bernard E. Sunny, president of the Chicago Telephone Company, made the principal address of the evening, on The Engineering of Chicago. Mr. Sunny outlined the various broad plans for the development of public utilities and municipal improvements in Chicago proposed during the last two or three years, embracing sewers and a high-pressure water system for the central business district, the steam railway terminals of Chicago, plans of the Board of Local Improvements for replacing pavements in the business district, deep waterways, harbors and subways. The "Chicago Plan" prepared by the Commercial Club of Chicago, was also given extended consideration, and Mr. Sunny suggested that a board of engineers be created to compile the necessary engineering data relative to such a plan.

NEW ENGLAND WATER WORKS ASSOCIATION

One hundred and fifty members and guests attended the annual meeting of the New England Water Works Association held at the Hotel Brunswick, Boston, Mass., on January 12, 1910. Papers were presented on Governmental Policy in Relation to Water Power

by Marshall O. Leighton, discussed by Dugald C. Jackson, Mem. Am.Soc.M.E., Geo. F. Swain, Mem.Am.Soc.M.E., and Dwight Porter; and on the Maidstone Typhoid Epidemic, by Wm. T. Mason, discussed by Robert S. Weston. Geo. A. King was elected president and Willard Kent, Secretary.

NECROLOGY

HORACE SEE

Horace See, President of the Society in 1888, died in New York City on December 14, 1909.

He was born in Philadelphia, and after the usual classical and mathematical education of the private school entered the shops of I. P. Morris. Thence passing to Neafie & Levy, and the National Armor and Shipbuilding Co., at Camden, and Geo. W. Snyder of Pottsville, he entered on his best known life-work with William Cramp & Sons.

He rose here to be designer and superintending engineer (in 1879), designing vessels and machinery of greatly improved construction and performance, introducing improved methods of work and standards in that great establishment, and giving to the United States a shipbuilding plant of capacity and quality to compare favorably with the products of the Clyde and Newcastle. It was under his leadership that the United States Navy contracts for the first vessels of what was then called the "New Navy of the United States" were taken, and the big ships of the American Line at that day bore his impress. It was at the zenith of this busy period, when he was confessedly the leader in his field, that the presidency of the Society was placed in his hands. He presided at the Nashville and Scranton meetings of 1888.

The following year it became apparent that avenues of professional advancement would not open further for him in Philadelphia, so that he came to New York with the honors thick upon him won from his busy years. He became at once consulting engineer for the Newport News Steamship and Dry Dock Company, and was the host of the Society on his visit to that plant at the Richmond meeting of 1890. He was superintending engineer for the Southern Pacific Company, and the Pacific Mail Steam Ship Co., superintendent for the Cromwell Steam Ship Co., and in his private practice as a marine engineer and naval architect he designed and prepared specifications for many yachts and commercial vessels. Some of his improvements in hull and machinery are in international use

Mr. See was adjutant of the Twentieth Regiment of the National Guard of Pennsylvania during the riots of 1877, and later Captain of the First Pennsylvania Regiment. Besides various business and social connections, he was a member of the American Society of Naval Architects and Marine Engineers, of the Institute of Naval Architects of Great Britain, as well as of the Northeast Coast Institute of Engineers and Shipbuilders, and the American Geographical Society; associate member of the American Society of Naval Engineers and the United States Naval Institute; and fellow of the American Association for the Advancement of Science.

He contributed a paper on the method he introduced for producing true crank shafts for multiple-cylinder engines[1] his presidential address was a discussion of manual training and methods of instruction for technical work.

STEPHEN WARNER BALDWIN

In the death of Mr. Baldwin there has passed away another of the notable figures in the engineering history of the United States. He belonged to the era of practical training which brought forward so many gifted men in the nineteenth century, and to take part in the active developments following the Civil War.

He was born in Baldwinsville, N. Y., February 4, 1833, and received his early education in Homer in that state. He entered the Lawrence Machine Shops at Lawrence, Mass., as an apprentice under the late John C. Hoadley, dividing his three years between the machine shop, forge, boiler shop, and drawing-room. The admiration he felt for Mr. Hoadley lasted all through his life, and on the death of his old chief, both out of affection and out of sentiment, Mr. Baldwin was active in buying from the Hoadley estate a large amount of expert apparatus, which was made a gift to the Society.[2] Mr. Baldwin worked with Mr. Hoadley on his single-valve automatic engines and on his portable or farm engines. From this experience he always had a strong interest in the development of agricultural machinery for the West.

He later became manager of the Clipper Mowing Machine Works at Yonkers, N. Y., and was associated with the Johnson Iron Works at Spuyten Duyvil, N. Y., improving the machines of both of these companies with his own inventions. He soon became one of the promi-

[1] Transactions, Vol. 7, p. 521.

[2] Transactions Vol. 8. p. 349. Some of this apparatus remains in the possession of the Society as museum specimens. Other units have been sold and loaned where thay could be made useful.

nent mechanical engineers in the field of manufacture of steel and was president of the Spaulding & Jennings Co. But he will be principally remembered as the New York representative and agent for so many busy and successful years for the Pennsylvania Steel Company and the Maryland Steel Company. He remained with these companies until 1904 when he was retired, but was an honored adviser until his death.

Mr. Baldwin was intensely interested in the problems of education for the young engineer. When Milton P. Higgins proposed his scheme of half-time schools in which lads were to work at books for half the day and in the shop atmosphere for the other half, Mr. Baldwin's interest was not alone because the projector had been a fellow apprentice at Lawrence, but because he believed the idea to be sound. The Artisan School of Syracuse, in which his friend Prof. John E. Sweet is so important a factor, was also near his heart.

Mr. Baldwin was early brought into active relations with the Society. He served on early nominating committees, was made Manager for the term 1887–1890 and Vice-President for 1890–1892, serving five continuous and important years on the Council. But his greatest service was as Chairman of the finance committee with control over the budget of each year. He was successively re-appointed fourteen times, and his service ceased only with the changes in constitution and by-laws in 1904. He was a member of the Council's Committee which bravely faced the problem of the purchase of No. 12 West 31st Street, in 1890, when the Society had no capital to invest in such a great undertaking, except the earnest purpose of those members whom the secretary of that date had stimulated to the point of venturesomeness. The bonds issued as a part of the financial scheme were all redeemed and the second mortgage paid off within the period of Mr. Baldwin's activity. He worked very hard for two winters over a plan to develop meetings of the junior members of the Society for their common advantage. The monthly meetings of the Society in different cities are an heritage from those efforts.

Mr. Baldwin was a sound and straight thinker, a man of great power of application, an analytical reasoner, a diligent and painstaking worker. Tall and commanding of figure, he had the grace, refinement and broad culture of the scholar. His inventive mind was always at work, adding labor-saving devices as well as improvements to whatever interested him, and his pleasing personality intensified the impression of good fellowship by which he put every one at ease. He inspired such confidence in his integrity that he was constantly

sought as an adviser. He was at one time a member of the American Society of Civil Engineers and of the American Institute of Mining Engineers. He was very active also with his friend J. F. Holloway in the building up of the Engineers Club, and was one of its four honorary members.

Mr. Baldwin died at the home of his daughter on January 5, 1910, after several years of physical weakness, although of clear mental capacity, and a personality active in the days of the up-building of the Society has gone to his reward.

CHARLES B. DUDLEY

Dr. Charles B. Dudley died at his home in Altoona, Pa., on December 21, 1909. He was born July 14, 1842, at Oxford, Chenango Co., New York, where he received his early education. In 1862 he enlisted as a private soldier in the 114th New York Volunteers and fought in seven battles, finally receiving a severe wound at the battle of Opequan Creek in 1864. Returning from the war in 1865, he prepared at the Oxford Academy and Collegiate Institute to enter Yale, from which he received the degree of A. B. in 1871; and in 1874, the degree of Ph.D. His graduation thesis, On Lithium and a Glass made with Lithium was published in full abstract in the Proceedings of the American Association for the Advancement of Science.

The following year he became assistant to Dr. George F. Barker, Professor of Physics at the University of Pennsylvania, and during this time published in the Franklin Institute Journal some translations of German technical papers. After a month spent as teacher of sciences at Riverview Military Academy, Poughkeepsie, N. Y., in November 1875 he went to Altoona to take up his life work as chemist of the Pennsylvania Railroad.

When Dr. Dudley entered upon his new task, no railroad had a chemist as a regular employee, although many had occasional chemical work done, and the whole subject of the relation between scientific knowledge and its practical use by railroads was in a very chaotic state. It would not be possible to enumerate the special investigations and studies leading to modifications of practices in daily use on railroads which have been considered since that time by the experimental department at Altoona, for the chemical part of which Dr. Dudley was responsible. That which attracted the most widespread attention, perhaps, was the study of steel rails, made in the early eighties, which gave the steel-maker as never before a view of

his product from the standpoint of the consumer and forced upon him a study of it not only for immediate output but also with an eye to the demands which service would make upon it.

Another very important line of work has been the making of specifications, perhaps the most exacting and time-consuming undertaken. Investigations have been made, furthermore, into the questions of ventilation, car lighting, steam heating of cars, disinfectants, cast iron for car wheels and other important uses, paints, long-continued tests on bearing metals, analyses of coals, water supplied both for boiler use and drinking, and explosives.

Dr. Dudley has been abroad on three important commissions; in 1886 to study oil burning on locomotives in Russia, in 1900 as a delegate to the International Railway Congress in France, and in 1909 as a delegate to the Convention of the International Society for Testing Materials in Denmark. He had been vice-president of the American Institute of Mining Engineers, and twice president of the American Chemical Society. At the time of his death he was president of the International Society for Testing Materials, as well as of the Bureau of Explosives of the American Railway Association. He was a member of the English, French and German Chemical Societies; of the Iron and Steel Institute of Great Britain; of the Verein deutscher Eisenhüttenleute; the American Society of Civil Engineers; the American Institute of Electrical Engineers; and social clubs in Philadelphia, Washington and New York. He was also much interested in the Altoona Mechanists' Library.

Dr. Dudley was a member of the Research Committee of the Society.

WILLIAM METCALF

William Metcalf was born at Pittsburg, Pa., September 3, 1838 and educated there and at the Rensselaer Polytechnic Institute, from which he was graduated in 1858. Immediately after graduation he went into the employ of the Ft. Pitt Foundry, as draftsman and afterwards as superintendent, and later joint proprietor. One of his chief duties as superintendent was the casting of mortars, shells and guns for the United States Government during the Civil War, at a time when the largest cast-iron guns ever made were being cast at this foundry.

Soon after the close of the war, Mr. Metcalf bought an interest in the firm of Miller, Barr & Parkin, later Miller, Metcalf & Parkin, and after incorporation in 1889 known as the Crescent Steel Company.

This company engaged in the manufacture of fine steel. In 1895, Mr. Metcalf retired from the Crescent Steel Company and in 1897 organized the Braeburn Steel Company, of which he was principal stockholder and president at the time of his death, December 5, 1909. His book, Steel, a Manual for Steel Users, is regarded as an authority.

Mr. Metcalf was a member and one-time president of the American Society of Civil Engineers and the American Institute of Mining Engineers, and first president of the Engineers' Society of Western Pennsylvania. He had served as vice-president of the American Iron and Steel Association, and was a member of the Institution of Civil Engineers of Great Britain. In addition he was a member of the Duquesne Club of Pittsburg, and the Century Association and Engineers' Club of New York, and was actively engaged in hospital and charity work. He was appointed by the United States Government one of seven appraisers for the condemnation of the property and franchise of the Monongahela Navigation Company, in March 1897.

Mr. Metcalf entered the Society in 1880 and was its vice-president from 1882 to 1884.

PERSONALS

Geo. M. Brill and Horace C. Gardner have formed a partnership under the name of Brill & Gardner, continuing the engineering and architectural practice heretofore conducted by Mr. Brill. Mr. Gardner was formerly manager of the construction and mechanical departments of Swift & Co. The offices will be in the Marquette Building, Chicago, Ill.

J. Ansel Brooks delivered an illustrated lecture on Aerial Navigation at the January 11 meeting of the Brown University Engineering Society, formerly known as the Brown University Society of Civil Engineers.

Prof R. C. Carpenter and E. H. Faile announce a partnership for the practice of engineering, with office at 68 William Street, New York. This change will not prevent the continuation of his duties at Cornell University by Professor Carpenter, who will take up his work of instruction again at the expiration of his present year's leave of absence from the University. Mr. Faile was formerly associated with the City Investing Company, New York.

A. C. Dinkey has been made a member of the board of trustees of the Carnegie Library, Pittsburg, Pa.

George W. Dunham has severed his connections with the Hudson Motor Car Company, and is now occupying the position of vice-president and consulting engineer, with the Chalmers-Detroit Motor Company, Detroit, Mich.

Wm. Wood Estes, of Providence, R. I., has taken a position with the chief engineer of the Rhode Island Co.

Edwin. J. Haddock has given up his office in Columbus, O., to accept a position with the Tennessee Coal, Iron and Railroad Company, as mechanical and structural engineer in the coal mining department.

Sir R. A. Hadfield has been elected a vice-president of the Faraday Society of London, for the next session, 1909-1910.

John T. Horton, formerly manager of the Dobbie Foundry and Machine Company, New York, has opened an engineering office at 95 Liberty Street, New York, specializing on machinery and appliances for hoisting and handling material and contractor's equipment.

Frederick H. Keyes, formerly general manager of the Robb-Mumford Boiler Company, has associated himself with Messrs. Timothy W. Sprague, Henry D. Jackson and others, to conduct a general consulting engineering practice in New York.

Walter Laidlaw, originally identified with the Laidlaw-Dunn-Gordon Co., Cincinnati, O., and general manager of the Snow Steam Pump Works, Buffalo, N. Y., is hereafter to be located at the New York office of the International Steam Pump Co.

J. W. Lieb, Jr., was elected vice-president of the National Society for the Promotion of Industrial Education at its annual convention at Milwaukee, December 2–4, 1909.

Walter M. McFarland, acting vice-president of the Westinghouse Electric and Manufacturing Company, East Pittsburg, Pa., has resigned to engage in other business.

W. K. Millholland, until recently secretary of the international Machine Tool Company, Indianapolis, Ind., has formed the W. K. Millholland Machine Company, Indianapolis, of which he is president.

Charles E. Rogers has become connected with the Johannesburg, South Africa, office of Fraser & Chalmers, Ltd. Until recently he was associated with the Melbourne, Australia, office.

L. H. Thullen, who has conducted a consulting practice in electrical engineering in New York, has recently accepted the position of chief engineer with the Triumph Electric Company, Cincinnati, O.

W. R. Warner presented a paper on Egypt and the Pyramids at the January 11 meeting of the Cleveland Engineering Society.

Earl Wheeler has resigned his position as director of the department of electrical and mechanical engineering, Engineer School, United States Army, to become electrical and mechanical engineer of the Electric Speedometer and Dynamometer Manufacturing Company, 1317-1319 New York Ave., Washington, D. C.

DEDICATION OF MEMORIAL TABLET TO ROBERT HENRY THURSTON

A bronze memorial tablet to Dr. Robert Henry Thurston, first president of The American Society of Mechanical Engineers, was dedicated at the New York monthly meeting, Tuesday evening, February 8, 1910, in the auditorium of the Engineering Societies Building, in the presence of many associates and former students of Dr. Thurston as well as of members of the Society. This bas-relief, which is the work of Herman A. MacNeil, a former student and personal friend of Dr. Thurston, and is a replica of the memorial tablet presented to Sibley College, Cornell University, by alumni and students, was placed in the rooms of the Society through the generosity of members, as an expression of their devotion to Dr. Thurston. The contributions were received by a committee consisting of John Fritz, S. W. Baldwin, Prof. R. C. Carpenter, Walter C. Kerr, E. A. Uehling, Wm. Hewitt and Gus. C. Henning; and the details connected with the acquiring of the tablet, its installation and the arrangement of the dedicatory exercises, were in the hands of Dr. Alex. C. Humphreys, *Chairman*, Chas. Wallace Hunt, Fred J. Miller, Prof. R. C. Carpenter and J. W. Lieb, Jr.

The program of the evening was designed to cover the various phases of Dr. Thurston's brilliant career, treated in each case by a speaker of wide reputation who had known Dr. Thurston intimately during this period of his life. It therefore very appropriately included an address on Dr. Thurston's relationship with the Society, by Prof. John E. Sweet, President of the Society from 1883–1884 and active with Dr. Thurston in its organization; a communication on Dr. Thurston's career as a naval engineer from Rear-Admiral Benjamin Franklin Isherwood, U.S.N., Retired, Honorary Member of the Society, which was read by Prof. F. R. Hutton, Honorary Secretary; an address on Dr. Thurston at the Naval Academy at Annapolis, by Rear-Admiral George W. Melville, U.S.N., Retired, Honorary Member and Past-President, Am.Soc.M.E.; on Dr. Thurston as professor at Stevens Institute of Technology, by Col. E. A. Stevens,

trustee and treasurer of Stevens Institute and son of its founder; on Dr. Thurston's literary and research work, by William Kent, one of the organizers of the Society and a close friend and co-worker with Dr. Thurston; and on Dr. Thurston as director of Sibley College, Cornell University, by Walter C. Kerr, a trustee of Cornell.

After the addresses of the evening, members and guests proceeded to the eleventh floor where the tablet was unveiled and presented by Dr. Humphreys, on behalf of the committee, to the Society, for whom it was accepted by Col. E. D. Meier, Vice-President. Col. Meier cites this as the first bronze statue of an eminent engineer to be erected in the United States in a great building devoted entirely to engineering and said that an excellent choice had been made of Dr. Thurston as a representative of his profession. Dr. Humphreys also presented Herman A. MacNeil, the artist, to the audience, who made the concluding remarks of the evening.

The addresses of the evening follow.

It was a matter of regret that Mrs. Thurston found it impossible to be present at the meeting. A letter was read by the Chairman, expressing her appreciation of the honor rendered to Dr. Thurston. Messages were also received from President Westinghouse, who was prevented by urgent business from attending, and from Chief Engineer Chas. H. Manning, U. S. N., and Lieut-Commander Robert Crawford, U. S. N., associated with Dr. Thurston in the Naval Academy at Annapolis.

The Chairman of the Thurston Memorial Committee, Dr. Alex. C. Humphreys, president of Stevens Institute of Technology, presided over the meeting, and said in his introductory remarks:

REMARKS BY DR. ALEX. C. HUMPHREYS, CHAIRMAN

While recognizing that it is not the function of a presiding officer to forestall the speakers to be introduced, I cannot refrain from saying a few words about my friend and preceptor, Robert H. Thurston. Others will tell you of his widely varied activities, his tremendous capacity for work, which was nevertheless overtaxed, his quickness of brain and speech, his powers of exact determination and expression, his capacity for organization and execution, his eminence as an engineer and educator. I prefer to think of him as the large-hearted, gentle, lovable, helpful man; the man of vision, the optimist.

While a student at Stevens, I was not fortunate enough to have Dr. Thurston's guidance during my junior year, for then, in 1879, he had

not yet recovered from the almost fatal nervous breakdown, which resulted from his strenuous life in many lines of activity. But I came to know him well during my senior year, and had many occasions to be deeply grateful to him for his assistance and encouragement, which I then greatly needed. I never saw him other than cheerfully responsive to a request for help, and I was never allowed to feel that I was intruding when I went to him for counsel. While demanding respect and obedience from those under him, his attitude towards them was characterized by a sympathetic desire to be helpful.

Wm. Kent, one of the speakers of the evening, in his masterly biographical notice of Dr. Thurston in the Sibley College Journal, in writing of the vast amount of work performed at a certain time by Dr. Thurston, says: "And during all this time, I never saw him excited or ruffled over his work." We busy, overcrowded men, know this to be high praise indeed.

I met Thurston too seldom after I graduated from Stevens, but when we did meet, I was made to feel that he was really interested in my career, and that he rejoiced and sympathized with me as circumstances suggested. I like to remember that he came down from Cornell at the time of my inauguration as president of Stevens Institute, and that it was through him that Cornell University and Sibley College conveyed their good wishes to Stevens Institute and to me at that time. Later in that year he quietly passed away to his well-earned rest.

Thurston was a man of vision. Time and again this is shown in his writings, and especially in view of later developments. And this, notwithstanding that his declared results were sometimes afterwards to be amended, as must be the case of those who are courageous enough to act the part of pioneers.

We are, apparently, now only beginning to appreciate in this country the practical and commercial value, to say nothing of higher things, of technical and technological education. And even now, those who do have the appreciation are unable to move and guide those who have the power to provide the means for the necessary improvement in our educational methods. Years ago, Thurston wrote: "Germany has substituted for the now obsolete apprenticeship system, the systematic, scientific methods of preparing her youth for the future of their lives in all departments of instruction and industry."

He was a student of political economy and education and pointed out the evils which would come to us unless certain lines of reform were followed, the evils which are now upon us and have to be met by patience, wisdom, firmness and common sense.

It was said of his father: "Throughout his life, his benevolence, his uniform kindness to employes and to all with whom he came in contact, and his strong attachment to his friends, made him as universally beloved as he was widely known."

The son was strong in faith though he did not carry his religion in his sleeve. He gave voice to his faith in a certain article which he wrote under the title, The Scientific Basis of Belief, which received wide attention. It seems to me that the summation of his creed is found in a verse which he included in this article:

> Strong Son of God, immortal love,
> Whom we, that have not seen Thy face,
> By faith, and faith alone, embrace,
> Believing where we cannot prove.

Notwithstanding his great and varied accomplishments, it is as the holder of this faith, and as the worthy son of this worthy father, that I love to think of Robert H. Thurston.

DR. THURSTON'S CONNECTION WITH THE SOCIETY

By John E. Sweet

Honorary Member and Past-President, Am.Soc.M.E.

We meet tonight to do honor to the first president of The American Society of Mechanical Engineers, elected now nearly thirty years ago. I have been asked to tell the simple story of his connection with the Society. It is fitting that we whose fading memories can give only shadowy reviews of past events do the best we can to record the facts as we recall them.

To begin at the beginning we must hark back to the fall of 1879, when the American Machinist was published in a small office at 96 Fulton St., New York. The journal had been in existence but a few years. It had received contributions from a goodly number of contributors engaged in various branches of mechanical industries and from a wide section of the country. But very few of these contributors were known to the publishers, and fewer still to one another, and the notion came to my mind to get as many of them together as we well could, and give the publishers a surprise party; with a faint notion that it might lead to an organization. I conveyed the notion to one of the contributors, and he at once gave it away to the editor, with the suggestion that some sort of a mechanical association be formed. The suggestion took root in the minds of

the publishers, and Mr. Bailey, the editor, came to Syracuse to see me about it; or, in fact, to inveigle me into writing the invitations.

Among those invited were Alexander L. Holley and Prof. Robt. H. Thurston, then in a sanitarium in Dansville, N. Y., both of whom entered heartily into the scheme. Before the meeting, which was held on February 16, 1880, Mr. Bailey and I had an interview with Mr. Holley; each was to draw up some form of program for the meeting, and we were to meet the next day to compare notes. As such things usually turn out, Mr. Holley had drawn up a set of rules which were so complete that we could readily endorse them. At the meeting in the afternoon there were something like thirty present, with letters of endorsement from fifteen or twenty others. Mr. Holley acted as chairman, and I well remember the point he made in his opening address, that it had come to that state of affairs that both civil and mining engineering were largely mechanical. A good deal of time was spent in discussion of the rules, which ended in the adoption of those Mr. Holley had prepared; and time was also wasted in settling on a name, until Mr. Copeland said, "Call it 'The Society of Mechanical Engineers.'" This seemed to settle it, except that in the shuffle the word "American" got incorporated, to the regret of possibly no one but myself.

Mr. Copeland, Charles T. Porter, Mr. Holley, E. D. Leavitt, Jr., and myself were chosen as a nominating committee. The officers nominated were elected at the meeting held April 7, 1880, at the Stevens Institute, over which Henry R. Worthington presided.

At the time of what is now known as the first annual meeting, held in New York, November 4 and 5, 1880, Professor Thurston had regained his health, and was able to preside and to deliver an able address. Professor Thurston was elected president for the second time, and these two were the critical years in the Society's history. We then held three meetings a year, and while Holley and Worthington lived, they formed with Professor Thurston a three-point support that did not rock; but they both died while Thurston was President, and left him to carry the burden. One incident that occurred during this time I shall always remember. Going out from one of the meetings Mr. Worthington, greatly elated over the way things were moving, said to me, "Professor, the thing is going to go." I doubt if any of us had the idea that the Society would reach a membership of 300, while today it takes another right hand cipher to record our membership.

Professor, later Dr. Thurston, not only while president, but for a

long time later, was more instrumental in helping up the Society than any other man. It is not necessary to enumerate his contributions to the Transactions. He never showed evidence of elation at success or chagrin at defeat. His work enriches every volume of the Transactions, from the first volume down to the time of his death. And every member of the Society needs to open the door of his memory and let the history of its work shine in and enliven his spirit of respect and adoration for the boy, the student and the scholar, the thinker and the worker, the teacher and the guide, the honored member and revered first President of The American Society of Mechanical Engineers, and the man—Dr. Robert Henry Thurston.

DR. THURSTON'S CAREER AS A NAVAL ENGINEER

By Rear-Admiral Benjamin F. Isherwood
Engineer-in-Chief, U.S.N., Retired, Hon. Mem. Am.Soc.M.E.

Professor Thurston, in whose honor these commemoration exercises are held, was in all respects an exceptional person, with endowments not only of a very rare but of a very high order. He was a typical representative of the American engineer of the present day; combining a thorough and extensive practical knowledge of his profession with a scientific culture scarcely found in the exclusively theoretical scientist; and he had, in addition, the ability to make these qualifications available to the world by means of an excellent literary education improved by a carefully discriminating practice as a writer, an orator, a mathematician, and an original investigator in the broad field of his profession. The first-class engineer of the present day must also be a first-class scientist as well as a first-class mechanician, besides possessing a mind well stored with the information collected by others of his profession whose aims and achievements are similar to his own.

With these mental powers was associated, in the case of Professor Thurston, so charming a personality that he not only never had a foe, but all who knew him were his friends. His knowledge and his services were at the command of all who sought them, and were rendered in a manner that made the recipient believe that instead of receiving a favor, he was conferring one. Professor Thurston was the author of several books on engineering subjects, which were classics in their day. He was also a prolific investigator of difficult phenomena in engineering, and his numerous reports have much

enriched its literature and enlightened its obscurities. He wrote with perspicuity, elegance and ease; and he was a ready and fluent orator on all the scientific topics of the day.

His death was a great loss to the world, and particularly to his own profession of engineering, for his exceptionally valuable life was devoted to the improvement of the world in the only way it could, in his opinion, be improved, namely, by the cultivation of physical science. Great intellectual attainment meant with him, great everything else.

Those who knew Professor Thurston best valued him the highest. My personal acquaintance with him was long and intimate, and it was intensified by our professional interest in the same subjects, notwithstanding the great difference of our ages and temperaments; and none who knew him as well as I did will consider this weak portraiture of him as overcolored. His death at Cornell saddened all who knew him well enough to appreciate his gentle qualities, as well as his lofty aspirations. He was most happily constituted; he lived his life in the sunshine of an entirely normal existence, and by dying in the full flush of manhood and in the consciousness of great achievement, he was saved from decline, and enabled to pay to glory the debt he owed to nature.

DR. THURSTON AT THE NAVAL ACADEMY AT ANNAPOLIS

By George W. Melville, Rear-Admiral, U.S.N., Retired
Honorary Member and Past-President, Am.Soc.M.E.

My function is to pay the tribute of the navy to one who was for a time a naval officer and who during his career as such bore himself in a way worthy of its best traditions, and left a record the memory of which is still distinct with those of us who were his contemporaries although it has long since been overshadowed by the greater reputation of his more mature life.

When the engineer came into the navy, he received scant recognition, although we were very fortunate indeed in having as our first representative that grand old man, Charles H. Haswell, who was taken from us so recently. The dominant faction in the navy did not like machinery nor mechanics, and as a result the very early engineers were largely men whose theoretical training did not go beyond the common schools and whose professional training came from hard knocks in the machine shop. This was true in my own

case and in that of the great majority of the older engineers. At the breaking out of the Civil War, however, with the increased demand for engineers and the desire of patriotic men with engineering training to render their best service to the Government, a number of men came into the corps who were college graduates, and Dr. Thurston was one of these. He entered the service in July 1861, very soon after the beginning of hostilities and before any of the great naval battles, and he served at sea continuously until the close of the war, taking part in the Battle of Port Royal and in the Siege of Charleston. While still a second assistant engineer, he was placed in charge of the machinery on the Chippewa and later served on the monitor Dictator, the largest built up to that time.

The historian of the engineer corps of the navy, Past Assistant Engineer (now Captain) Frank M. Bennett has mentioned several instances in which Thurston distinguished himself. One of these was on January 29, 1863, when he was in command of one of the armed boat's crews which captured the blockade runner Princess Royal at Charleston. The next day two armored rebel rams came down upon the Federal fleet and destroyed some of the converted merchantmen which constituted it. Thurston was temporarily chief engineer of the Princess Royal and by extraordinary efforts managed to get the machinery going so that she got out to sea and escaped destruction at the hands of the rebels.

With his fine preliminary training at Brown University and his four years of practical experience in the navy, it was obvious that he was well equipped for duty as an instructor at the Naval Academy in the department of natural and experimental philosophy, to which he was ordered in 1865. During his term of service there, the head of the department died and Thurston was made acting head of the department.

It was during this time that the education of engineers at the Naval Academy began with the class of acting third assistant engineers who entered in 1866, of whom the late Admiral Rae was a member. Thurston undoubtedly gave instruction to all of these young engineers in that department, which we would now call thermo-dynamics, although he was not a member of the department of engineering which looked after the more practical side of their professional training.

A retired engineer officer, who was an instructor at Annapolis in the department of engineering, while Dr. Thurston was in the department of physics, speaks of him as follows: "During about two years

of his term at Annapolis, I saw him almost daily and am therefore able to bear testimony to the excellent work he then did both as an instructor and as the managing head of that very important department of our Naval School. He fully appreciated the importance of physical science to the naval profession generally, and its particular application to naval engineering, and he worked with untiring zeal for its full development as a part of the training of our young officers, often personally designing special apparatus, which were fewer then than now, for demonstrating physical truths and principles. Thurston was eminently fitted for this class of scientific work by taste, education and practical experience as a naval engineer.

At such a time as this, we realize how very interesting it would be if we could know exactly what circumstances lead to the selection of a man for a particular line of work. I have tried hard to find just what led to Dr. Thurston's selection for the chair of mechanical engineering in Stevens Institute, but it occurred so long ago, almost forty years, that the details are no longer available. Indeed it is probable that there never was any record of them and that it was a matter between President Morton and Dr. Thurston himself. Unless a man writes an autobiography, and is as frank about all the occurrences of his life as Herbert Spencer, such an interesting phase as this is apt to be entirely passed over in spite of its great importance. Aware, as those of us who knew him well are, of Thurston's marked ability as a scientific expositor and of his life-long desire for progress and increased efficiency, may we not imagine that, before he was asked to become President of Stevens, President Morton had become acquainted with Dr. Thurston through his articles; and by correspondence or conversation had found that here was a man after his own heart, who could be counted upon to make the new school of technology what he wanted it to be, the best in the country.

There were other departments of colleges and perhaps other schools where mechanical engineering was taught, but Stevens was, I believe, the first institution in our country devoted exclusively to the education of mechanical engineers, and we can now realize even better than when he was called to the Chair, how extremely important was the selection of Dr. Thurston for this work. If he had been content to drift along in accordance with old established methods, or if he had not been a tremendous worker, his great ability would have failed to give to Stevens the foremost standing which it has held from the very start.

Dr. Thurston had, in a degree rarely found among men devoted

to education, a strong touch of the commercial instinct, and it was doubtless this which led him, from the beginning, to direct the work of his students in their experiments along lines of an immediately practical interest to engineers and others. For example, I remember a set of experiments to determine the economy of gas engines at a time when they were just coming into use. This was only one of a great many instances. The hard-headed, practical manufacturers could not fail to realize that a school where the energies were directed in such a practical way must turn out men who would make good in practical life. I need hardly show that this judgment has been verified by recalling the positions now held in offices of the very highest importance in the lines of manufacturing and transportation by many of these graduates.

So great was the reputation made by Dr. Thurston at Stevens, that he was generally looked upon as the greatest teacher of mechanical engineering in the country; and I happen to have information with respect to the circumstances under which he went to Cornell which show that when they were looking for a man of the highest accomplishments to take charge of Sibley College, they at first did not consider Dr. Thurston, for the reason that they did not believe any inducement could take him away from Stevens. When the Trustees of Cornell came to the conclusion that they wanted the best man available, and that they were willing to pay whatever was necessary to secure his services, they eventually opened negotiations with Dr. Thurston, which led to his finally going there.

Of his splendid work at Cornell others will speak, and I need only say that it is a marvelous tribute to his ability and reputation that he should have been able to increase the attendance at Sibley College from about one hundred students to over one thousand.

His educational work was so engrossing that it naturally left him little time for keeping up his association with the Navy although we who remained in the service always felt that in him we had a sincere friend on whom we could depend for such help as was in his power to give whenever the engineers of the Navy needed assistance. Before we finally attained the full recognition of the paramount importance of engineering in the Navy, which, as you know, is now the function of the entire line of the Navy, we had many an up-hill fight, and on several occasions Dr. Thurston materially assisted us by articles in the magazines and by personal appeal. In this connection it is interesting to note that Bennett's History of the Steam Navy, in speaking of an order of the Navy Department in

1870, which was considered very unfair to the engineer corps, mentions that, in consequence of this order, a number of the brightest men in the corps resigned, among them Dr. Thurston. It has been my observation that the participants in an up-hill fight are drawn more closely together than those whose association is always on the winning side. It was doubtless Dr. Thurston's keen recollection of the lack of recognition which he had received while an engineer in the Navy, that made him so willing to help those who were still in the service in their efforts for a proper recognition and consideration of engineering and its exponents.

It has been my desire as a naval engineer and one whose whole life has been spent in the naval service, to voice, in behalf of myself and my colleagues who were and are engineers in the Navy, our admiration for the friend who, during his own short naval career, did so much to add to the reputation of the engineer corps, and by his prominence as an engineer all through his life reflected the highest credit upon naval engineering.

DR. THURSTON AT STEVENS INSTITUTE OF TECHNOLOGY

By Col. E. A. Stevens

Member of the Society, Trustee and Treasurer, Stevens Institute

Thurston's work at Stevens can be divided into two parts: on the one hand his general work as an engineer, including his well known contributions to the literature of engineering and the researches on which they rested, and on the other his share in the development of the work of the Institute and the influence of his personality on his fellow instructors and the undergraduates.

As to the first part I can say but little in the time assigned. The history of mechanical engineering in the United States will always bear witness to his ability, to his untiring energy and to the liberality with which he freely gave to his beloved profession all that his ripe experience and trained observation could give.

Whatever may have been the value of his other work while at Stevens, none of it surpasses, or I may say equals in importance, his share in the development of the system of instruction and the influence of his personality and of his standard of professional ethics on those with whom he was there thrown into contact.

Forty years ago the American mechanical engineer was mainly

the product of the shop and the engine room, with such self-teaching as could be gathered in the leisure hours of a busy life of hard work. Most engineers of that day would admit that draughting and mathematics could be taught in schools, but claimed that such training would produce draughtsmen and mathematicians, not engineers, men who would be of less value in practical work than the lad of the same age who had spent his time in the shop; that the school-bred man would need several years of hard work to knock the school-taught nonsense out of his head, always granting that he had not been irretrievably ruined by his scholastic training.

Such was the general, even if not the unanimous mind of the profession when Henry Morton gathered around himself six men, who with him were to form the faculty of the first American school wholly devoted to the teaching of mechanical engineering. Scientist and scholar as he was, Morton appreciated the gravity and importance of the task set him and selected his fellow members of the faculty with a care and judgment amply justified in the result. Of these men, eminent as they were, Thurston was the one on whom devolved the practical teaching of engineering. The others must have aided, and unquestionably did aid, in giving the training as a whole a practical direction, but it was to Thurston more than to any one other of Morton's first faculty that the prominence of the practical curriculum at Stevens must have been due, and on him therefore it is but fair to bestow a generous share of the acknowledgment due these men. It would be as invidious as it would be useless to apportion to each the share due to his individual efforts.

While Thurston's personality impressed itself on all who met him, whether at Stevens or elsewhere, the lasting result of this impression on the men who there studied under and with him forms a part of the history of Stevens. The material that came to the "Old Stone Mill" was much the same in the early days as since. The early graduates at once took a standing in American engineering work that soon settled once and for all any debate as to the value of a technical training. They carried also with them into the world what was as necessary for the progress of engineering as technical skill or practical knowledge. They had imbibed together with their calculus and thermodynamics that moral and ethical view of their profession without which an engineer's skill and learning is of little value to his country, a thing not absorbed from text books or taught by platitudes, however often reiterated from the lecture platform.

Boys and young men quick to detect cant are equally quick to

recognize and value square-dealing and to love and follow and model themselves after the straightforward man. Of all of that first faculty there was no one to whom the undergraduates could and did more confidently look for a square deal than to Thurston. That straight clear gaze, right into your eye, gave at once a confidence in the man and in his methods in and in a feeling of sympathy that experience did not belie.

Single examples prove few cases and a life such as Thurston's is not to be judged by citing examples and incidents. The true measure of his great work and usefulness is to be fixed by the standard set by the great Master, "by their fruits ye shall know them." By no other standard would Thurston have asked to be judged and the fruits of his work at Stevens are proven not by the accomplishment of specially gifted men who studied under him but by the general standing of the Stevens men of this day.

DR. THURSTON IN LITERATURE AND IN RESEARCH

By Wm. Kent, Mem.Am.Soc.M. E.

My acquaintance with Dr. Thurston began near the end of the year 1874, when I called upon him to make arrangements for entering the junior class in the Stevens Institute of Technology. He was then thirty-five years of age. He was at this time professor of mechanical engineering, meeting his classes two hours a day for, I think, five days in the week; he was editing the four volumes of reports of the United States Commission to the Vienna Exhibition of 1873, one of the volumes being written by himself; he had shortly before written a report of the United States Commission for investigating the causes of steam-boiler explosions; he was planning the researches to be made by the United States Board to test iron, steel and other metals, of which he was secretary and the most active member. Besides all this he was writing papers for the American Society of Civil Engineers and for the Journal of the Franklin Institute, concerning the results of his researches. In 1871 he had conducted a series of boiler tests on several different makes of water-tube boilers at the American Institute fair in New York. In 1873 he had organized a mechanical engineering laboratory for the purpose of making engineering researches, the first of the kind to be established in the United States. At about the same time he invented his well-known autographic testing machine for testing materials by torsion, and

later he invented the machine for testing lubricants, in which some of the principles of the torsion machine were embodied.

In June 1875, Dr. Thurston called me into his office and told me he wanted me to undertake a research into the strength and other properties of the alloys of copper. I said to him, "I don't know anything about alloys." "That is a good qualification," said he, "you won't have anything to unlearn." He told me how to make a research into the literature of the subject, and how to find indexes to such literature. He had me write him a report of all I could find that was then known about the alloys of copper and tin and copper and zinc, and after studying it he planned a series of tests to be made in the laboratory, which took eighteen months to complete. During all this time I had to report to him almost every day, and I had a desk in his office. Then began an intimate friendship which lasted until the day of his death. During these two years of companionship I was ever more and more impressed with Dr. Thurston's genius and with the breadth of his intellectual power. Not only was he a tireless worker, driving the pen or pounding the typewriter hour after hour, but his brain always seemed to be working as steadily and as rapidly as his pen. Whenever he was asked a difficult question the answer seemed to come instantly from his well-stored mind, and the answer was right. Such a combination of industry, rapid and clear brain-action, and broad intellectual grasp of a great variety of subjects, engineering and other, I have never known in any other man.

Such intense mental activity as Dr. Thurston exhibited in these years led to its natural result, nervous exhaustion. There was a time in 1876 when he visited the Institute only for a few minutes each day, and five minutes conversation on any technical question would almost prostrate him. During this time he was worried by the fear that Congress would not continue the appropriation for the work of the United States Test Board, and he undertook to write a letter on the subject to one of the senators, but it took him a week or more to write the letter working on it five minutes a day. He gave me a copy of it to take to one of the members of the board in New York City, and that member said to me that it was by far the best presentation of the subject that had ever been made. Such was the quality of his work when he was on the verge of physical collapse.

Here is another example of the kind of work he could do during the same period. He had been planning a series of tests of the triple alloys of copper, tin and zinc, and one day on one of his brief

visits to the institute he said to me: "Here is something I want to show you. Here is an equilateral triangle. It is one of the properties of this triangle that if from any point within it perpendiculars are drawn to each of the sides the sum of these perpendiculars is equal to the altitude. Now let us mark one apex 100 copper, another 100 tin, and the third 100 zinc, and the opposite sides zero copper, tin and zinc. Then any point in the triangle represents one alloy, and all the possible points represent all the possible alloys of the three metals. Now divide each altitude into ten parts, and through the points of division draw lines parallel to the three sides. The crossing points of these lines represent all the alloys whose constituents are even multiples of ten per cent. We will make these alloys and determine their tensile strength, and we will cut a lot of straight wires to lengths corresponding to the strength; then we will set these wires vertically on a board which has the triangle drawn upon it, in holes drilled at the points representing the alloys. We will then fill in this forest of wires with plaster of paris, smoothing it off so as just to leave the tops of the wires visible. We will thus have a topography which shows the complete law of the relation of the tensile strength of the triple alloys to their composition." I well remember my amazement when he had completed the description, that a man with such a worn-out brain should be capable of such a brilliant piece of intellectual work and invention. The investigation of the triple alloys was carried out exactly as he had planned it, and the results were published in the Reports of the United States Test Board, and in Dr. Thurston's book on Alloys.

In 1873 Dr. Thurston discovered the phenomenon of the elevation of the elastic limit of iron and steel. It was also discovered independently in the same year by Commander L. A. Beardslee, U.S.N. In years following he tried to find other metals or alloys that exhibited the same peculiar action after being strained beyond their elastic limit, but never found one. In 1874 he investigated the burning of tan bark for fuel in specially constructed boiler furnaces, and in 1875 and 1876 he made a number of tests of steam boilers. For some years after 1876 he carried on investigations of lubricants, the results of which are in his book on Friction and Lost Work. In later years his researches were not numerous or important, for the reason that his time was fully occupied with other work. It is a matter for lasting regret that the work of the United States Iron and Steel Test Board was discontinued almost before it was fairly started, and before the Watertown testing machine, which was built for its use, was finished.

Dr. Thurston was an omniverous reader, and a tremendously active writer. Prior to 1880 most of his technical writings were contributed to the American Society of Civil Engineers and to the Journal of the Franklin Institute. After that date his engineering papers were mostly given to The American Society of Mechanical Engineers.

Dr. Thurston's literary work was not confined to engineering matters. In 1873 he contributed to the Scientific American a series of seventeen articles on his observations in Europe, which included not only what he had seen at the Vienna Exhibition, and in the several iron works that he visited, but also his reflections on social conditions in the manufacturing centers. Here is a quotation from his remarks on the inferiority of workmanship which then characterized many European productions:

> A liberalization of patent codes, and the gradual training of the workmen of Europe to a knowledge of the importance of good workmanship, and of the methods of securing it, will at a time which we hope is not far distant, do much toward the improvement of the condition of the people. We draw some of our best material from amongst them, and it seems sufficiently evident that not upon nature but upon man's own imperfect political systems lies the responsibility of the unsatisfactory condition of manufactures in Europe.

Dr. Thurston's first important book after his report of the Vienna Exhibition was his History of the Growth of the Steam Engine, published by Appleton in 1878. It is written in his best style, and to those who are at all interested in the subject it is as readable as a novel. It illustrates his painstaking care to be sure of his facts, his skill in arranging them in logical order, and his good judgment in drawing conclusions. In 1877 he brought out a little book on Steam Boiler Explosions in Theory and Practice.

In 1879 he had his second and last nervous breakdown, more serious than the first, so that he was compelled to spend more than a whole year in a sanitarium, doing no work of any kind. He returned to work in 1880, and then followed twelve years of most intense literary activity, during which he brought out an average of a book every year, some of them large octavos of 1000 pages. Here is a list of the books whose first editions appeared in the years 1882 to 1894 inclusive:

The Materials of Engineering. 3 vol. I, Non-metallic materials; II, Iron and Steel; III, Brasses, Bronzes and other Alloys.

A Text Book of Materials of Construction.

Treatise on Friction and Lost Work in Machinery and Millwork.

Manual of Steam Boilers, their Design, Construction and Operation.

Handbook of Engine and Boiler Trials, the Indicator and the Prony Brake.

Translation of Sadi Carnot's "Reflections on the Motive Power of Heat and on Machines fitted to Develop that Power."

Life of Robert Fulton.

Manual of the Steam Engine. 2 vol. I, History, Structure and Theory; II, Design, Construction and Operation.

Stationary Steam Engines, Simple and Compound.

The Animal as a Machine and Prime Motor, and the Laws of Energetics.

Many of these books ran through several editions; the second volume of Materials of Engineering, Iron and Steel, is now in its ninth and the Treatise on Friction and Lost Work, the Manual of Steam Boilers, and Stationary Steam Engines, are each in their seventh edition. The work of revising these books to keep them up to date was no small labor, and several of them have as many as four copyright dates. The Manual of the Steam Engine, and the Handbook of Engine and Boiler Trials, have been translated into French.

Most of these books are severely technical and of interest only to engineers and engineering students; but two of them, the translation of Carnot's little book and The Animal as a Machine, appeal also to those interested in advanced physics. He translated Carnot not because he thought the book would sell, but as he says in his preface, "as a matter of limited but most intense scientific interest," and he compliments the publishers for their undertaking to print the book without any prospect of financial return. Yet in seven years a second edition was printed. Dr. Thurston's appreciation of Carnot in the introduction is a good example of his literary style when writing on non-technical subjects.

> Nicholas-Leonard-Sadi-Carnot was perhaps the greatest genius in the department of physical science that this century has produced. By this I mean that he possessed in the highest degree that combination of the imaginative faculty with intellectual acuteness, great logical power and capacity for learning, classifying and organizing in their proper relations all the facts, phenomena and laws of natural science, which distinguishes the real genius from other men and even from simply talented men. Only now and then in the centuries does such a man come into view. Euclid was such in mathematics, Newton was such in mechanics, Bacon and Comte were such in logic and philosophy, Lavoisier and Davy were such in chemistry, and Fourier, Thomson, Maxwell,

and Clausius were such in mathematical physics. Among engineers we have the examples of Watt as inventor and philosopher, and Rankine as his mathematical complement, developing the theory of that art of which Watt illustrated the practical side.

But Carnot exhibited that most marked characteristic of real genius, the power of applying such qualities as I have just enumerated to great purposes and with great result while still a youth. Genius is not dependent, as is talent, upon the ripening and the growth of years for its prescience; it is ready at the earliest maturity, and sometimes earlier, to exhibit its marvelous works; as for example note Hamilton, the mathematician, and Mill, the logician, the one becoming master of a dozen languages when hardly more than as many years of age, reading Newton's Principia at sixteen, and conceiving that wonderful system, quaternions, at eighteen; the other competent to begin the study of Greek at three, learning Latin at seven, and reading Plato before he was eight. Carnot had done his grandest work of the century in his province of thought and had passed into the Unseen at 36; his one little volume, which has made him immortal, was written when he was but 23 or 24.

A fine example of Dr. Thurston's grasp of a subject of scientific thought beyond the domain of engineering, and even beyond the present borderland of physics, is seen in the following brief extract from The Animal as a Machine:

> The living body is a machine in which the law of Carnot, which asserts the necessity of waste in all thermodynamic processes and in every heat engine, and which shows that waste to be the greater as the range of temperature worked through by the machine is the more restricted, is evaded; it produces electricity without intermediate conversions and losses; it obtains heat without high temperature combustion; and in some cases light without any sensible heat. In other words, in the vital system of man and of the lower animals, nature shows us the practicability of converting any one form of energy into any other, without those losses and unavoidable wastes characteristic of the methods, the invention of which has been the pride and the boast of man. Every living creature, man and worm alike, shows him that his task is but half accomplished; that his grandest inventions are but crude and remote imitations; that his best work is wasteful and awkward. Every animate creature is a machine of enormously higher efficiency as a dynamic engine than his most elaborate constructions. Every gymnotus living in the mud in tropical stream puts to shame man's best effort in the production of electricity; and the minute insect that flashes across his lawn on a summer evening, or the worm that lights his path in the garden, exhibits a system of illumination incomparably superior to his most perfect electric lights . . . Here is Nature's challenge to man. Man wastes one-fourth of all his fuel as utilized in his steam boiler, and often 90 per cent as used in his fireplace; nature in the animal system utilizes substantially all.

Dr. Thurston was an occasional contributor to such journals as the Popular Science Monthly, the Forum, Science, and the North American Review. Sometimes he went outside of the field of the

physical sciences and wrote on sociological and economic subjects, such as the tariff. Once he wrote for the North American Review a statement of his religious convictions.

He frequently wrote papers and delivered addresses on educational subjects, and in these he was naturally at his best. For nearly forty years he was an educator and an educational leader. He was versed in the theories of Froebel, Milton and Comenius; and of Spencer, John Scott Russell and other modern writers. His paper on Technical Education in the United States; its Social, Industrial and Economic Relations to our Progress, read at the International Engineering Congress at Chicago in 1893, is one of his masterpieces. It is a calm, scholarlike review of the conditions of the past, and a hopeful view of the future. He propounded no new theories, he originated no new fads, but he was in line with the best thinkers of his time, and thoroughly in sympathy with the modern trend toward industrial or trade education for the great mass of the people.

DR. THURSTON AT SIBLEY COLLEGE, CORNELL UNIVERSITY

By Walter C. Kerr, Mem, Am.Soc.M.E., Trustee Cornell University

What a man is, makes less difference to the world than what his life teaches; the man departs, but his teaching remains. It would be impossible for me to relate here the full importance of the eighteen years that Dr. Thurston devoted to Cornell University. Prior to 1885 Cornell was developing a department of mechanic arts in a small way, recognizing the necessity and opportunities of mechanical engineering. With a profitable sale of the university's timber lands the trustees felt warranted in taking forward steps, chief among which was the founding of a new department, and to this department of mechanical engineering Dr. Thurston was called as the first director. No choice was ever more fortunate. I will not undertake to recount all that followed in physical development from his administration, except to say that the number of students increased from one hundred to eleven hundred, buildings grew, facilities grew, everything that his hand touched grew, and all the growth was healthy. Professor Thurston was especially an organizer, and of the very best kind. This was because he knew what to organize. His methods were direct and practical, he knew men, he understood human nature; and all resistance was to him merely a retardation, not a stopping, and consequently he gained whatever he set out to do.

By temperament, education and experience he was peculiarly fitted to direct socially and intellectually an important department in a complex institution; by his touch with all the forces of life he was an important factor in any community in which he lived, and this gave him a profound and wide influence for good through a much larger circle than that of engineering. He convinced men, by persuading them to want what he wanted, and the result was that he usually gained his end with the minimum of argument. His ever-present cheerfulness was an inspiration, and his patience was an example. There is no subtle mystery about why he was so loved and respected at Cornell, nor why he accomplished so much. His ways were ways of peace, and his achievements were a series of creative victories. He was a strong man, so strong that we honor his memory tonight. He has gone, but the influence of his life lives.

TEST OF A 15,000-KW. STEAM-ENGINE-TURBINE UNIT

H. G. Stott, New York
Member of the Society

R. J. S. Pigott,[1] New York
Non-Member

During the year 1908 it became apparent that owing to the cost increasing traffic in the New York subway, it would be necessary to have additional power available for the winter of 1909–1910.

2 The power plant of the Interborough Rapid Transit Company, which supplies the subway, is located on the block bounded by 58th and 59th Streets, and by 11th and 12th Avenues, adjacent to the North River; it contains nine 7500-kw. (maximum rating) engine units, besides three 1250-kw. 60-cycle turbine units which are used exclusively for lighting and signal purposes.

3 The 7500-kw. units consist of Manhattan-type compound Corliss engines, having two 42-in. horizontal high-pressure cylinders and two 86-in. vertical low-pressure cylinders. Each horizontal high-pressure cylinder and vertical low-pressure cylinder has its connecting rod attached to the same crank, so that the unit becomes a four-cylinder 60-in. stroke compound engine with an overhanging crank on each side of a 7500-kw. maximum rating 11,000-volt, three-phase, 25-cycle generator. The generator revolving field is built up of riveted steel plates of sufficient weight to act as a flywheel for the two engines connected to it. This arrangement gives a very compact two-bearing unit. The valve gear on the high-pressure cylinders is of the poppet type, and on the low-pressure of the Corliss double-ported type.

4 The condensing apparatus consists of barometric condensers,

[1]Interborough Rapid Transit Company.

The American Society of Mechanical Engineers, 29 W. 39th St., N. Y.
All papers are subject to revision.

arranged so as to be directly attached to the low-pressure exhaust nozzles, with the usual compound displacement circulating pump and simple dry-vacuum pump.

5 These engine and generator units are in general probably the most satisfactory large units ever built, as five years' experience with them has proved; their normal economic rating is 5000 kw., but they operate equally well (water rate excepted) on 8000 kw. continuously.

6 In considering the problem of how to get an additional supply of power, every available source was considered, but by a process of elimination only two distinct plans were left in the field.

7 The electric transmission of power from a hydraulic plant was first considered, but owing to the high cost of a double transmission line from the nearest available water power, and the impossibility of getting reliable service (that is, service having a maximum total interruption of not more than ten minutes per annum) from such a line, further consideration of this plan was abandoned.

8 The gas engine, while offering the highest thermo-dynamic efficiency at the same time required an investment of at least 35 per cent more than an ordinary steam-turbine plant with a probable maintenance and operation account of from four to ten times that of the steam turbine.

9 The reciprocating-engine unit of the same type as those already installed, was rejected in spite of its most satisfactory performance, on account of the high first cost and small range of economical operation. Reference to Fig. 1, Series A will show that the economic limits of operation are between 3300 kw. and 6300 kw.; beyond these limits the water rate rises so rapidly as to make operation undesirable under this condition, except for a short period during peak loads.

10 The choice was thus narrowed down to either the high-pressure steam turbine or the low-pressure steam turbine. There was sufficient space in the present building to accommodate three 7500-kw. units of the high-pressure type, or a low-pressure unit of the same size on each of the nine engines, so that the questions of real estate and building were eliminated from the problem.

11 The first cost of a low-pressure turbine unit is slightly lower than that of a high-pressure unit, due to the omission of the high pressure stages and the hydraulic governing apparatus, but the cost of the condensing apparatus would be the same in both cases. The foundations and the steam piping in both cases would not differ greatly. The economic results, so far as the first cost is concerned, would then be approximately the same, if we consider the general

case only; but in this particular instance the installation of high-pressure turbines would have meant a much greater investment for foundations, flooring, switchboard apparatus, steam piping and water tunnels, amounting to an addition of not less than twenty-five per cent to the first cost.

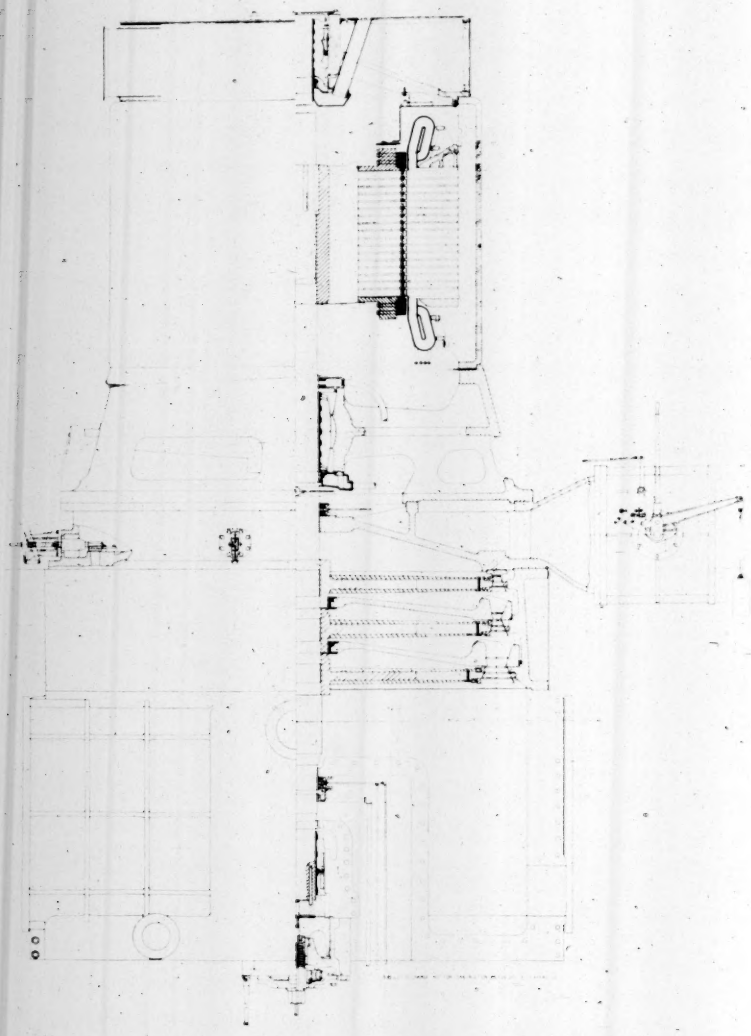
12 The general case of displacing reciprocating engines and installing steam-turbine units in their place was also considered. The best type of high-pressure turbine plant has a thermal efficiency approximately 10 per cent better than the best reciprocating-engine plant, but the items of labor for operation and for maintenance, together with the saving of about 85 per cent of the water for boiler-feed purposes and the 10 per cent of coal, reduce the relative operating and maintenance charges for the steam-turbine plant to 80 per cent, as compared to 100 per cent for the reciprocating-engine plant.

13 Assuming that the reciprocating engine plant is a first-class one and has been well maintained, about 20 per cent of its original cost (for engines, generators and condensers) may be realized on the old plant and so credited to the cost of the high-pressure turbine plant. But on the other hand, if the high-pressure turbine installation is to receive credit for the second-hand value of the engines, it must also have a debit charge for 100 per cent of the original reciprocating-engine plant which it displaced. The relative investments, therefore, upon this basis would be approximately equal for the high-pressure or the low-pressure turbine; but 80 per cent of the cost of the original engine plant would have to be charged against the high-pressure turbine plant, as against an actual increase in value (to the owner) of the engine by reason of its improved thermal efficiency, due to the addition of the low-pressure turbine.

14 The preliminary calculations, based upon the manufacturers' guarantees for the low-pressure and high-pressure turbines, showed that the combined engine-turbine unit would give at least 8 per cent better efficiency than the high-pressure turbine unit, so that it was finally decided to place an order for one 7500-kw. (maximum rating) unit, as by this means we would not only get an increase of 100 per cent in capacity, but at the same time give the engines a new lease of life by bringing them up to a thermal efficiency higher than that attained by any other type of steam plant.

15 The turbine installed is of the vertical three-stage impulse type having six fixed nozzles and six which can be operated by hand, so as to control the back pressure on the engine, or the division of load between engine and turbine. An emergency overspeed governor,

which trips a 40-in. butterfly valve on the steam pipe connecting the separator and the turbine and at the same time the 8-in. vacuum



ELEVATION AND PART SECTION OF LOW-PRESSURE TURBINE UNIT

breaker on the condenser, is the only form of governor used. The footstep bearing, carrying the weight of the turbine and generator rotors, is of the usual design supplied with oil under a pressure of

600 lb. per sq. in. with the usual double system of supply and accumulator to regulate the pressure and speed of the oil pumps.

16 The condenser contains approximately 25,000 sq. ft. of cooling surface arranged in the double two-pass system of water circulation with a 30-in. centrifugal circulating pump having a maximum capacity of 30,000 gal. per hr. The dry vacuum pump is of the single-stage type, 12-in. and 29-in. by 24-in., fitted with Corliss valves on the air cylinder. The whole condensing plant is capable of maintaining a vacuum within 1.1 in of the barometer when condensing 150,000 lb. of steam per hr. when supplied with circulating water at 70 deg. fahr.

17 The electric generator is of the three-phase induction type, star-wound for 11,000 volts, 25 cycles and a speed of 750 r.p.m. The rotor is of the squirrel-cage type with bar winding connecting into common bus-bar straps at each end. This type of generator was chosen as being specially suited to the conditions obtaining in the plant.

18 With nine units operating in multiple, each one capable of giving out 15,000 kw. for a short time, operating in multiple with another plant of the same size, it is evident that it is quite possible to concentrate 270,000 kw. on a short circuit. If we proceed to add to this, synchronous turbine units of 7500-kw. capacity, which, owing to their inherently better regulation and enormous stored energy, are capable of giving out at least six times their maximum rated capacity, the situation might soon become dangerous to operate, as it would be impossible to design switching apparatus which could successfully handle this amount of energy. The induction generator, on the other hand, is entirely dependent upon the synchronous apparatus for its excitation, and in case of a short circuit on the bus-bars would automatically lose its excitation by the fall in potential on the synchronous apparatus.

19 The absence of fields leads to the simplest possible switching apparatus, as the induction generator leads are tied in solidly through knife switches, which are never opened, to the main generator leads. The switchboard operator has no control whatever over the induction generator, and only knows it is present by the increased output on the engine generator instruments.

20 The method of starting is simplicity itself—the exciting current is put on the engine generator *before* starting the engine, and then the engine is started, brought up to speed and synchronized in exactly the same way as before. While starting in this way, the induction

generator acts as a motor until sufficient steam passes through the engine to carry the turbine above synchronism, when it immediately becomes a generator and picks up the load. Three of these 7500-kw. low-pressure turbine units have been installed and tests run on Nos. 1 and 2. No. 3, having been just started, has not yet been tested.

21 Instead of inserting in this paper the enormous accumulation of data incident to these tests, we have divided the paper into two parts in the hope that it would thus be more accessible for reference, the first part giving the reasons for adopting this particular type of apparatus, with a brief description of the plant and a summary of the results obtained, and the second part containing all the principal data acquired during the tests, with sufficient explanation to make their meaning clear without reference to the text.

22 The tables and curve sheets are as follows:

Series A: Engine tests made in connection with acceptance tests, and also later to determine best conditions for operation.

Series B: Calculations and data furnished by turbine manufacturer to determine probable results when combined with engine data obtained in Series A.

Series C: Tests on No. 1 combined unit. This unit was hurriedly put into commission in order to obtain results to determine future developments. To get the piping done, old riveted steel pipe was used which was very leaky under vacuum. Results are valuable however as showing the effect of vacuum on performance as compared to Series E and F. Quality of steam entering turbine also poor.

Series D: Tests of No. 2 unit, with poor vacuum and poor quality of steam entering turbine.

Series E and F: Tests on No. 2 combined unit; conditions of vacuum and quality of steam entering turbine nearly standard, so that corrections are small.

23 In all results, except where specially noted, moisture corrections are simple corrections, i. e., for each per cent of moisture only one per cent correction has been made. Vacuum corrections for the combined unit are 1 lb. for each inch variation from 28.5 in. when referred to 29.92 in. barometer.

24 The net results obtained by the installation of low-pressure turbine units may be summarized as follows:

a An increase of 100 per cent in maximum capacity of plant.
b An increase of 146 per cent in economic capacity of plant.
c A saving of approximately 85 per cent of the condensed steam for return to the boilers.
d An average improvement in economy of 13 per cent over the best high-pressure turbine results.
e An average improvement in economy of 25 per cent (between the limits of 7000 kw. and 15,000 kw.) over the results obtained by the engine units alone.
f An average unit thermal efficiency between the limits of 6500 kw. and 15,500 kw. of 20.6 per cent.

NUMBER OF TEST	ENG LOAD	STEAM PR. Gauge	STM TEMP	STM SUPER-HEAT	RECEIVER PR (Gauge from Temp)	VACUUM Std. 29.92" Bar "Hg	QUALITY STM	WATER PER HR	DRY STM P HR	REC DRAIN P HR	STM TO AUX's	INJECT WATER TEMP	DISCH. WATER TEMP	I.H.P. H.P.	I.H.P. L.P.	I.H.P. TOTAL	DRY STM P.KW.H.	DRY STM. per I.H.P.H.	
	K.W.	Lbs.G.	°F	°F	Lbs.G.		%	Lbs.	Lbs.	Lbs.	Lbs.	°F.	°F	H.P.	H.P.	H.P.	Lbs.	Lbs.	
25	3100	180.1	388.3	9.7	9.13	28.81	100.55	56040	56343	2989	1517	36.8	55.7	2173	2306	4479	18.18	12.58	
22	4008	176.7	383.9	5.7	16.87	27.99	100.32	68190	68407	4882	1866	38.4	58.3	2699	2815	5514	17.07	12.42	
24	4577	174.4	387.8	10.6	21.7	28.00	100.58	85365	85865	5273	2949	36.8	65.3	3264	4076	7341	17.25	11.70	
21	5984	173.9	387.5	10.5	25.9	28.00	100.60	103896	104519	6031	1699	37.73	69.5	3717	4714	8431	17.47	12.40	
23	6772	173.3	385.5	8.7	30.0	27.71	100.50	124702	125326	6060	2091	37.7	70.4	4346	5732	10078	18.51	12.37	
27	4992	173.9	387.3	10.5	10.44	28.11	100.60	89525	90062	5367	1826	37.76	72.66	3770	5184	8954	18.04	12.95	
26	4970	173.2	386.1	9.4	15.21	28.00	100.53	86267	86724	5518	1728	35.9	61.1	3443	3452	6895	17.45	12.58	
29	4976	174.9	386.9	9.4	20.41	28.00	100.53	85557	86010	5234	3034	38.1	75.0	3124	3722	6846	17.29	12.59	
28	4970	174.3	388.8	11.7	25.35	28.02	100.66	85933	86501	4890	663	36.7	72.6	2982	4127	7109	17.42	12.17	
31	3988	177.7	387.5	8.9	32.62	—	100.51	109317	109874	5948				2625	2372	4997	27.55	21.99	
32	4980	176.2	386.7	8.7	36.93	—	100.50	128056	128695	6352				2835	3333	6168	25.84	20.88	
30	4961	148.2	372.0	7.0	21.06	28.04	100.40	88041	88394	5082	1284	37.46	72.4	3068	4019	7087	17.82	12.48	

TABLE I. SERIES A, ENGINE TESTS

NUMBER OF TEST	ENG LOAD KW	B.T.U. ADDED PER POUND WATER	B.T.U. REJ. PER POUND WATER	EFF. RANKINE %	EFF. THERMAL %	$\frac{EFF_T}{EFF_R}$ %	B.T.U. DRAINS %	B.T.U. CONS'R & RADN. LOSS %	B.T.U. MECH. ELEC. LOSS %	REMARKS
25	3100	1205	840	30.3	15.7	51.7	0.9	71.4	12.0	
22	4008	1202	865	28.0	16.7	59.6	1.3	70.0	Do.	
24	4977	1204	866	28.1	16.5	58.1	1.2	70.3	Do.	
21	5984	1204	866	27.1	16.3	58.2	1.1	70.6	Do.	
23	6772	1203	875	28.3	15.4	56.4	1.0	71.6	Do.	
27	4992	1205	865	28.2	15.8	56.0	1.0	71.2	Do.	
26	4970	1204	866	28.1	16.3	58.1	1.2	70.5	Do.	
29	4976	1205	866	28.1	16.4	58.6	1.2	70.4	Do.	
28	4970	1206	866	28.2	16.4	58.1	1.1	70.5	Do.	
31	3988	1205	1017	15.6	10.3	66.2	1.1	76.6	Do.	Non-condensing
32	4980	1204	1017	15.5	11.0	71.1	1.0	76.0	Do.	Non-condensing
30	4961	1200	875	27.1	16.0	59.7	1.1	70.9	Do.	

TABLE 2 SERIES A.

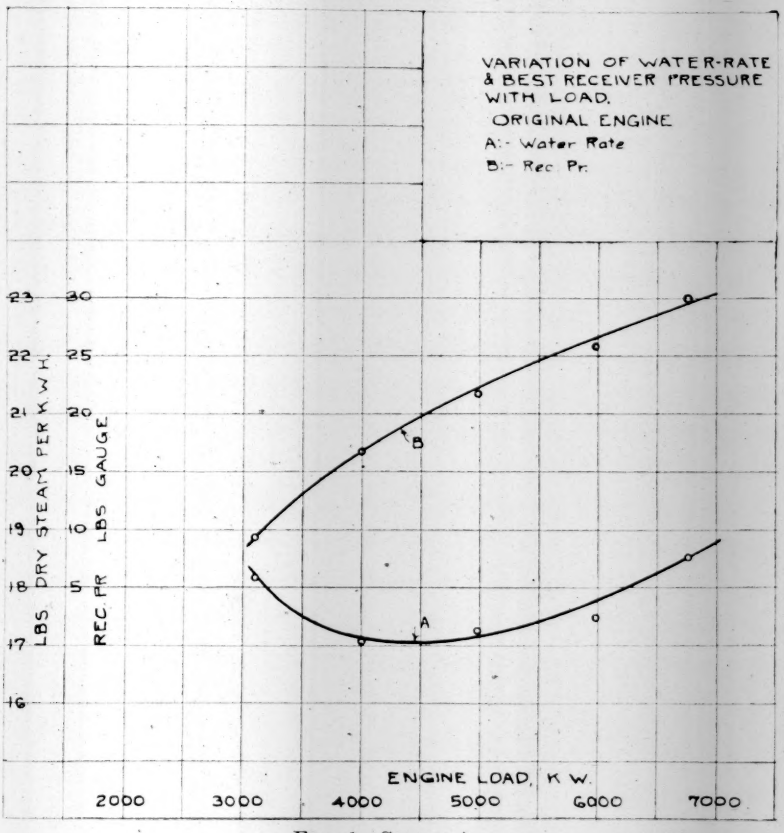


FIG. 1 SERIES A

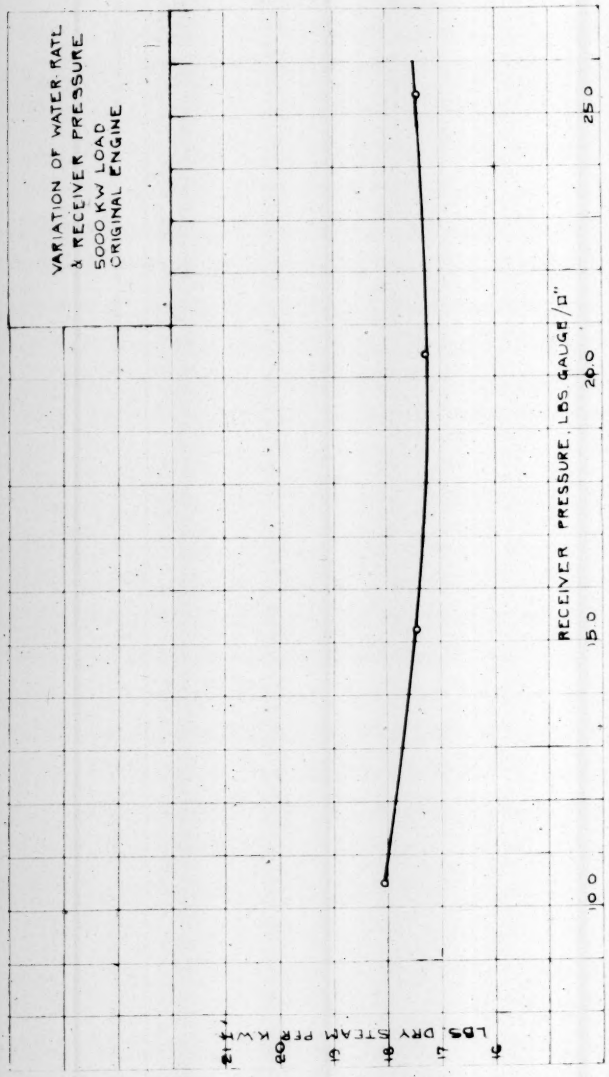


FIG. 2 SERIES A

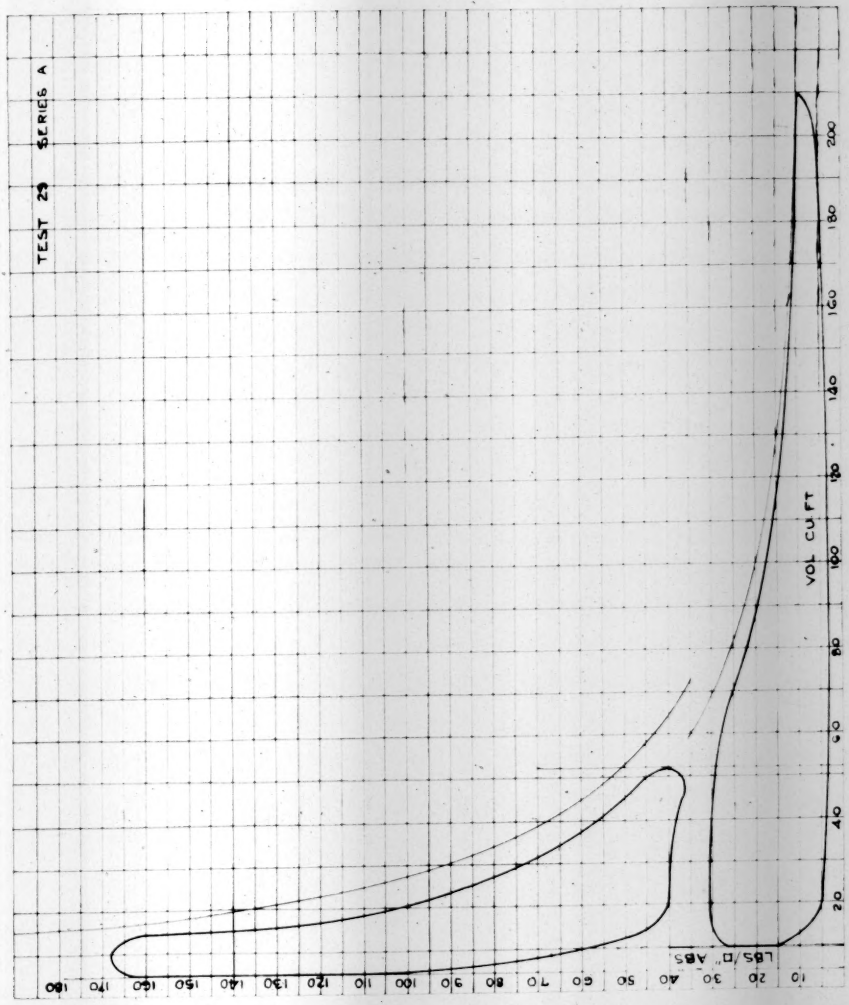


FIG. 3 SERIES A, TEST 29

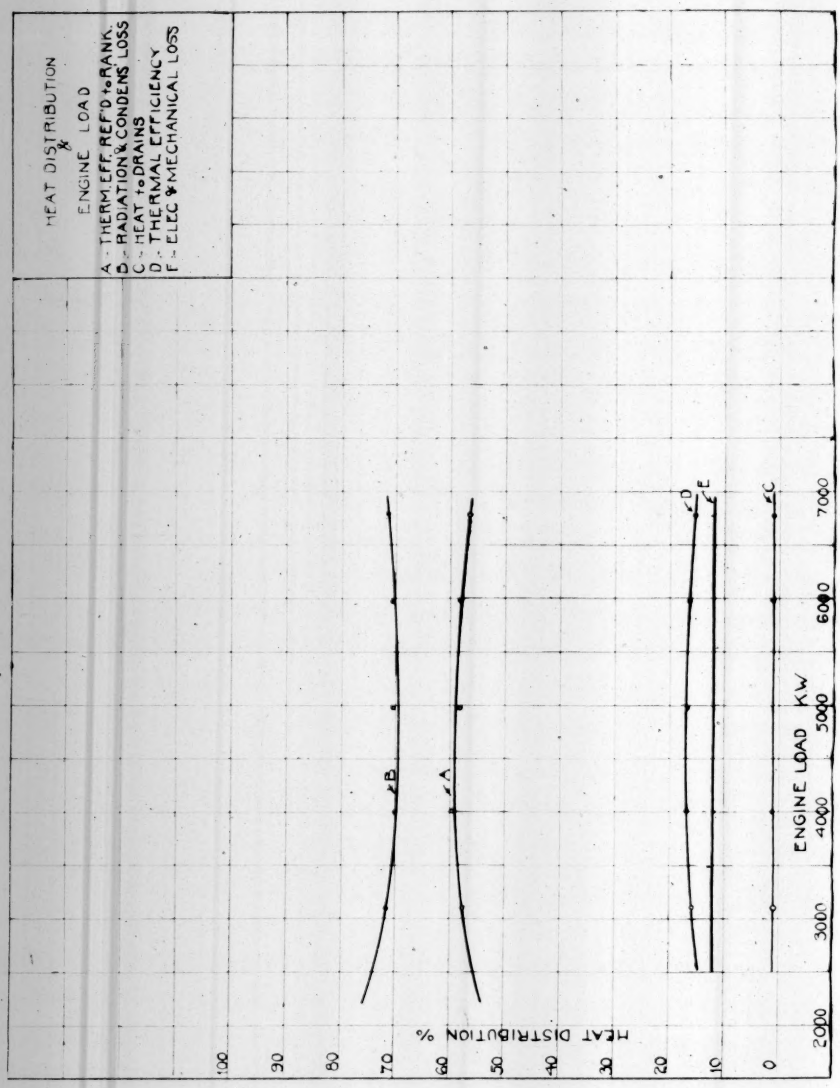


FIG. 3a SERIES A

NO TEST	LOAD KW	LOAD IHP	RATIO HP/LP IHP	p_a Lbs/□" Abs	p_c Lbs/□" Abs	V_a Cu Ft	V_c Cu Ft	w_a Lbs/Cu Ft	w_c Lbs/Cu Ft	STM PER STROKE H.P CARD Lbs	r	y	INDIC WATER RATE per I.H.P Lbs/Hr	ACTUAL WATER RATE per I.H.P Lbs/Hr	ACTUAL WATER RATE per K.W.H Lbs/Hr	RECEIVER PRESS Lbs/□" Abs	EXHAUST PRESS Lbs/□" Abs	STM. PRESS. Lbs/□" Abs	TOTAL WATER Lbs/Hr
25	3100	4479	.943	137.32	66.12	10.78	7.56	.3058	.1544	2.131	4.80	.409	8.57	12.59	18.18	18.8	9	191.5	56349
22	4008	5515	.959	143.0	65.3	13.77	9.31	.3176	.1526	2.351	3.41	.298	9.64	12.41	17.07	31.6	10	192.8	68407
23	4976	6846	.840	142.4	73.8	16.64	9.30	.3163	.1705	3.670	3.11	.302	9.65	12.56	17.29	36.4	10	190.9	86010
24	4977	7341	.801	141.8	75.7	17.13	9.30	.3151	.1751	3.763	3.32	.265	9.24	11.68	17.25	35.1	9	191.0	85865
21	5984	8431	.789	141.8	74.1	21.48	9.29	.3142	.1716	5.154	2.42	.128	11.00	12.40	17.47	40.6	9	191.0	104519
23	6772	10078	.759	140.6	88.0	25.40	9.29	.3126	.2037	6.080	2.04	.154	10.86	12.44	18.51	44.7	10	190.9	125326
31	3988	5900	1.403	143.7	72.2	19.83	7.56	.3191	.1675	5.058	3.11	.206	15.43	18.62	27.59	47.3	14.7	192.2	109874
32	4981	7004	.807	143.7	75.8	23.44	7.57	.3151	.1753	6.154	2.21	.155	15.81	18.28	25.84	51.6	14.7	189.7	128695
ASSUMED CARDS, VARIABLE NOZZLE PRESSURE																			
A	4050	5936	1.04	187.8	82.5	10.93	4.70	4.107	1.857	3.537	4.73	.474	12.00	17.69	25.92	33.7	7.0	21.5	105000
B	5590	8192	1.05	182.2	96.0	16.45	"	.3951	.2186	5.537	3.14	.268	12.18	15.45	22.63	46.0	10.0	"	126600
C	6710	9836	1.07	176.0	113.5	22.80	"	.3862	.2685	7.55	2.27	.156	13.62	15.98	23.40	52.2	13.5	"	157300
D	7370	10792	1.10	188.6	122.8	29.83	"	.3708	.2753	9.71	1.73	.087	16.30	17.72	25.95	58.5	18.0	"	191100
E	7740	11336	1.05	160.9	136.2	37.60	"	.3549	.3034	11.92	1.31	.033	18.91	19.54	28.61	64.7	23.0	"	221400
ASSUMED CARDS, CONSTANT NOZZLE PRESSURE																			
F	3875	5676	1.12	182.2	136.2	16.45	"	.3951	.3034	5.140	3.14	.268	16.31	20.69	30.30	64.7	16.0	"	117400
G	5795	8484	.988	176.0	"	22.80	"	.3862	"	7.374	2.27	.156	15.57	18.00	26.38	"	"	"	152700
H	7180	10540	.974	168.6	"	29.83	"	.3708	"	9.633	1.73	.087	16.45	17.88	26.20	"	"	"	188500
I	8200	12008	.958	160.9	"	37.60	"	.3549	"	11.92	1.31	.033	17.86	18.45	27.04	"	"	"	221700

TABLE 3 SERIES B

ASSUMED CARDS — L P EXHAUST QUALITY DATA

NO	WATER p. Hr. Lbs	H.P. STM. TO L.P CYL %	MOISTURE at L.P Adm %	ADM PR L P Abs Lbs/□"	REL PR L P Abs Lbs/□"	EXH PR L P Abs Lbs/□"	r	QUAL OF L.P EXHAUST %	COMB. QUAL %	DRY STM. TURB. Lbs/Hr.	
A	105000	93.2	2.5	37	9.5		2.76	90.6	84.4	88600	VNP
B	126600	94.3	3.0	43	14		2.47	90.9	85.7	108500	"
C	157300	95.2	3.5	49	19		2.26	91.4	86.9	136700	"
D	191100	95.9	4.0	55	24		2.10	91.6	87.8	167800	"
E	221400	96.2	4.0	60	28		1.98	91.9	88.4	195600	"
F	117400	96.8	3.0	60	20	17.5	3.30	90.8	84.5	99200	CNP
G	152700	95.7	3.5	"	20	"	2.94	90.5	85.5	130600	"
H	188500	94.4	4.0	"	23	"	2.46	90.8	86.9	163800	"
I	221700	93.1	4.0	"	27	"	1.98	91.6	88.7	196600	"

REMARKS & FORMULAE

TESTS 21 – 29 INCLUSIVE, 8 HRS.

TESTS 31 – 32, 8 HRS. ATMOSPHERIC EXHAUST NON-CONDENSING

$\frac{IHP}{KW} = 1.465$

$r = \frac{51.7}{V_a}$ for HP Card = Ratio of Expansion

$y = 0.129 (r - 1.06)$ = Missing Water

ω = Sp. density @ p

$W_a \times V_a = \overline{W_1}$ $\quad W_c \times V_c = \overline{W_2}$ $\quad \overline{W_1} - \overline{W_2} = \overline{W_3}$

$\frac{\overline{W_3} \times 60 \times 4 \times 75}{IHP} = IWR$ @ HP Cut-off

$IWR \times (1+y) = AWR/IHP/HR.$

TABLE 4 SERIES B

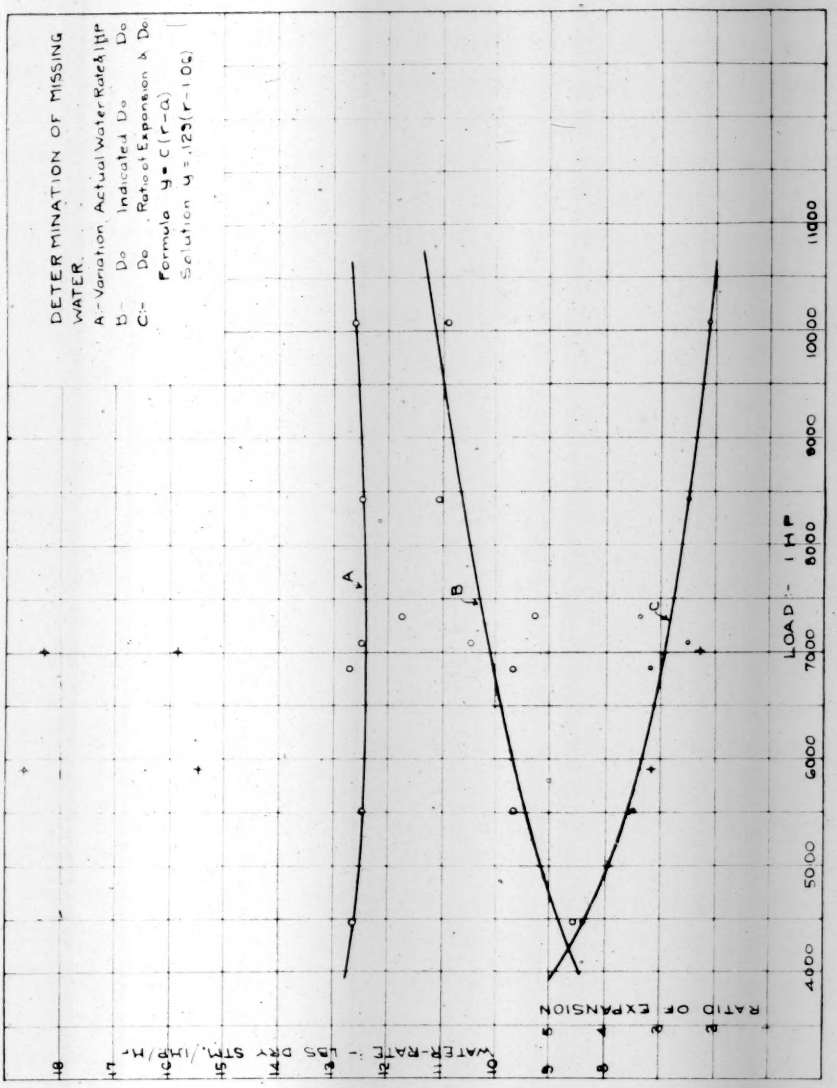


FIG. 4 SERIES B

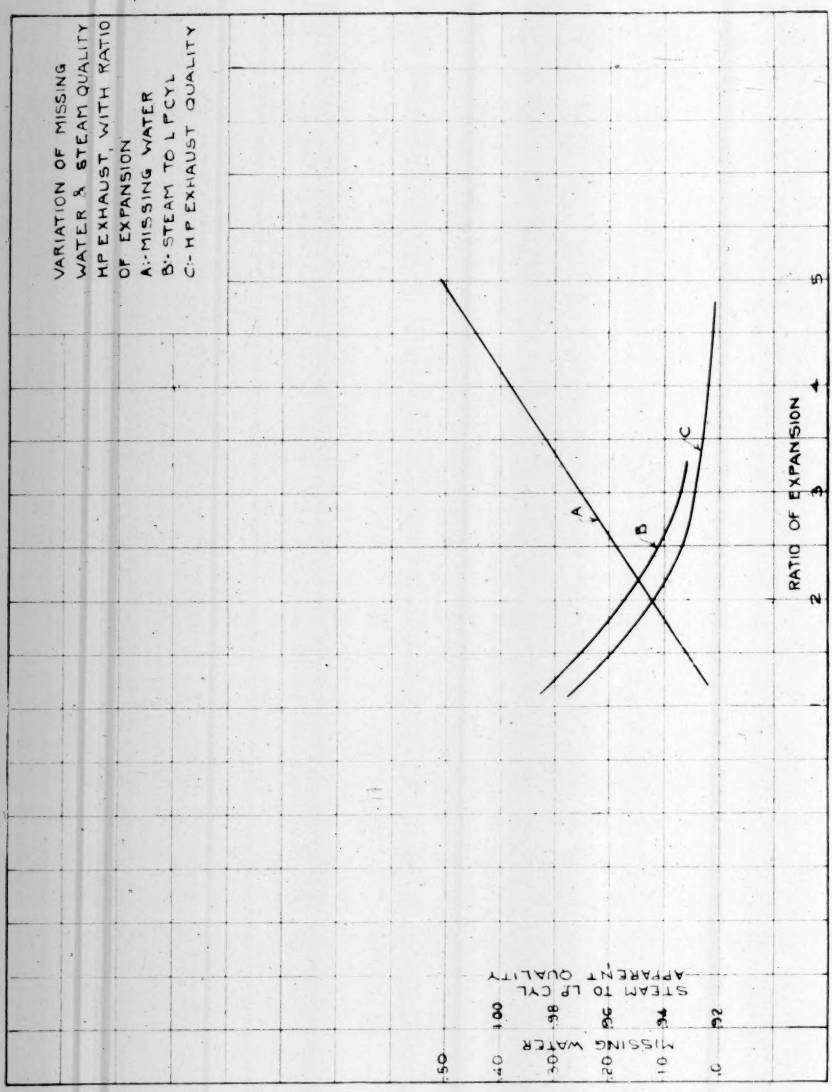


FIG. 5 SERIES B

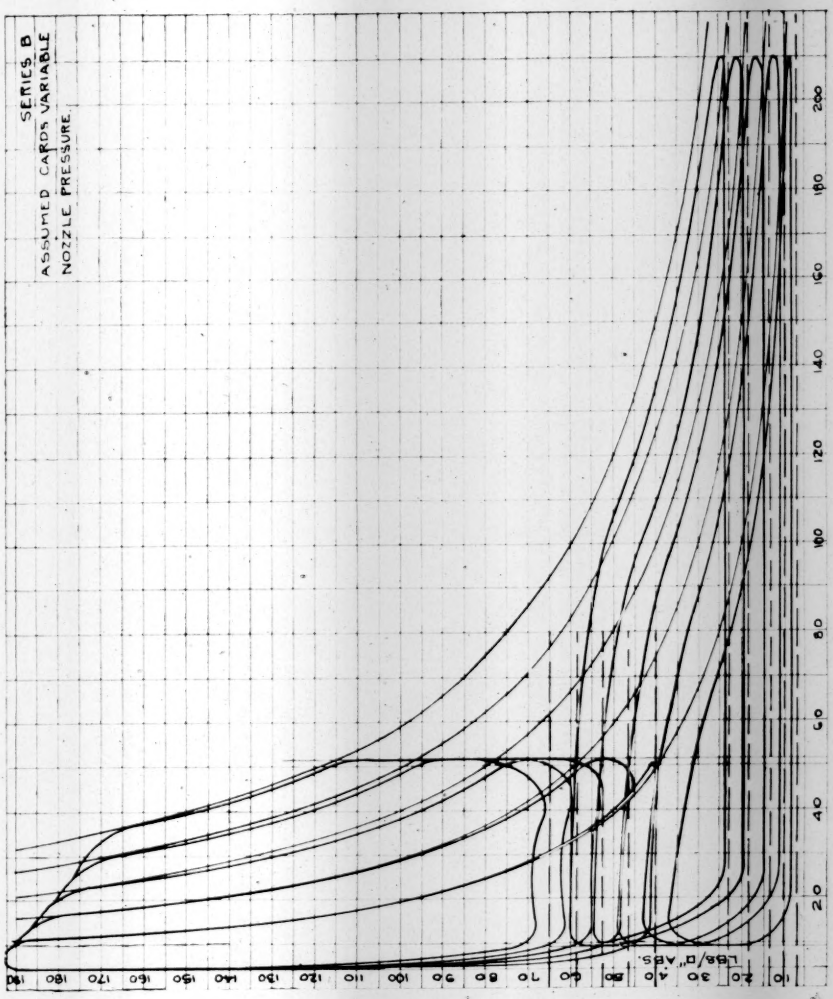


FIG. 6 SERIES B

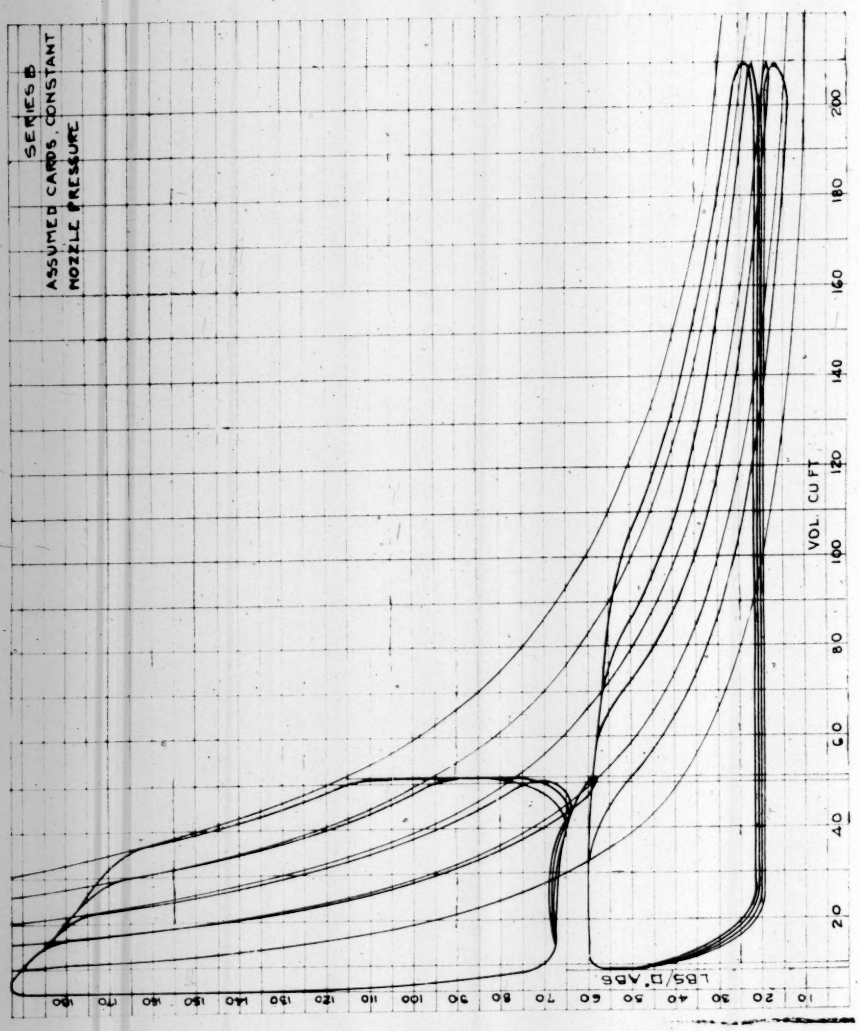


FIG. 7 SERIES B

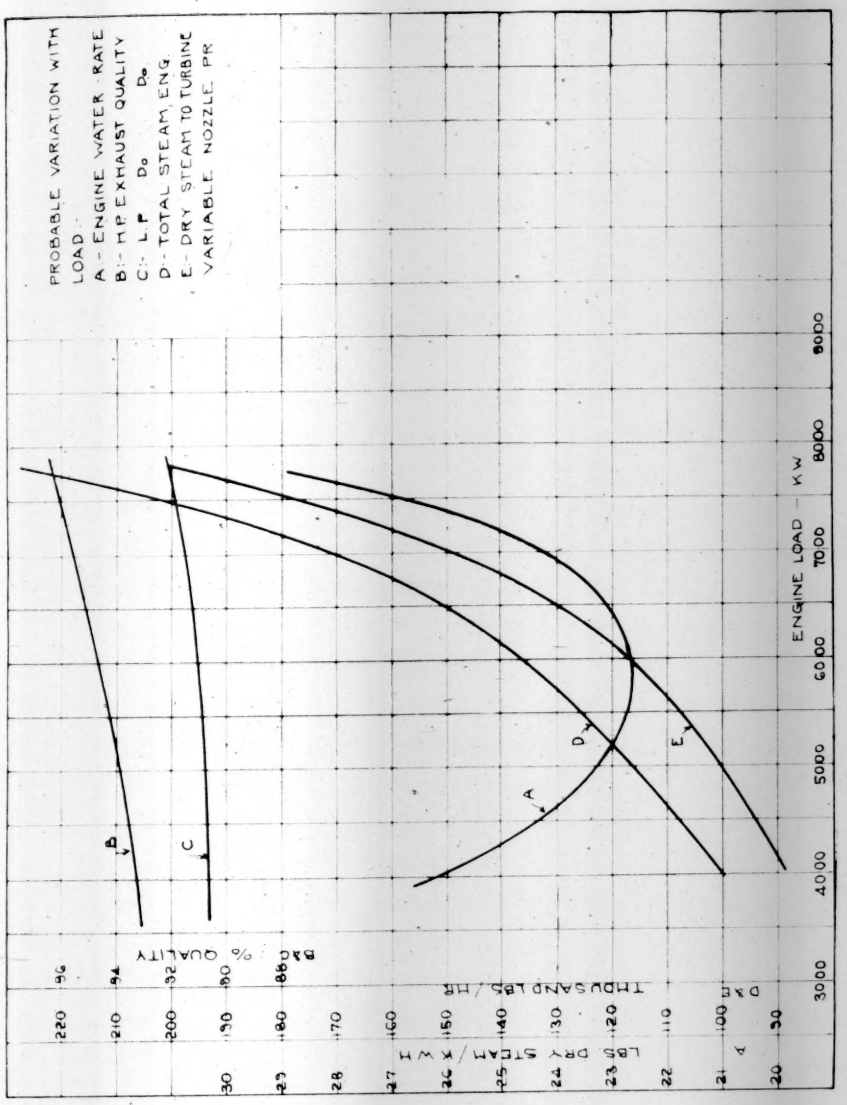


FIG. 8 SERIES B

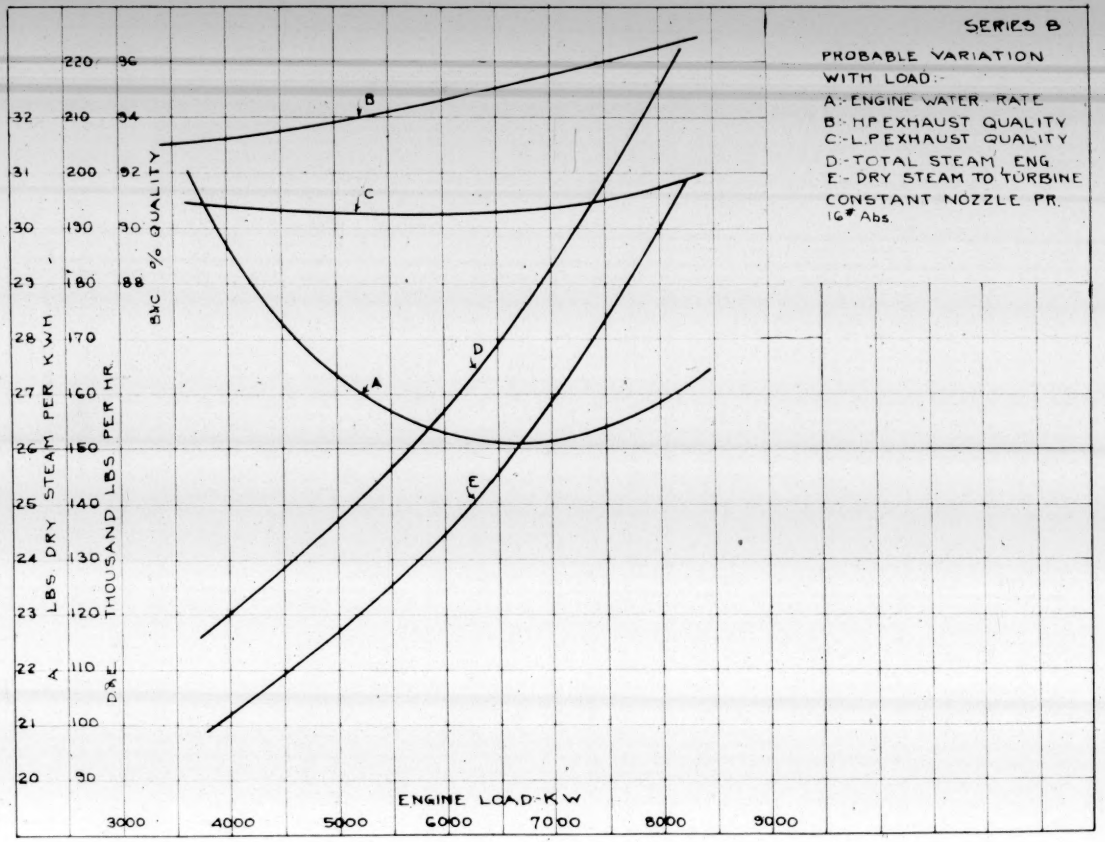


FIG. 9 SERIES B

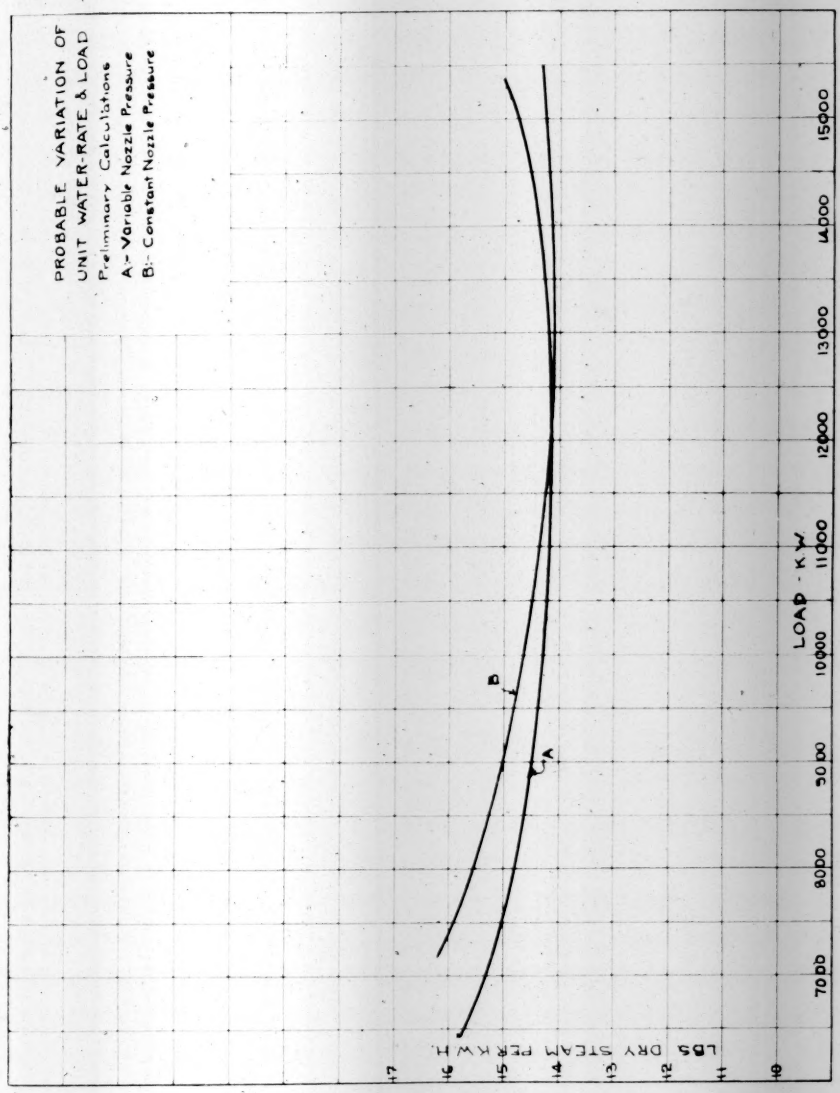


FIG. 10 SERIES B

RESUME' OF OBSERVATIONS — CORRECTED TO 29.92 BAR & 14.7 ATMOS

TEST NUMBER	DURATION	LOADS			PRESSURES					QUALITIES		WATER			DRY STEAM		TEMPERATURES		
		UNIT	ENGINE	TURBINE	H.P STEAM	RECEIVERS	L.P STEAM	L.P STEAM	VACUUM	H.P STEAM	L.P TURB	SEPARATOR L.P	TURBINE DISCH.	TOTAL UNIT	TURBINE	ENG. & UNIT	HOT WELL COND	INJECTION	DISCH CIRC WATER
	Hours	K.W	K.W	K.W	Lbs Gauge p □"	Lbs Gauge p □"	Lbs Abs. p □"	Lbs. Gauge p □"	Ins. Hg.	%	%	Lbs per Hour	Lbs. per Hour	Lbs per Hour	Lbs per Hour	Lbs per Hour	°F	°F	°F
5	4	10220	6627	3690	174.4	36.2	12.72	—	28.03	97.08	90.89	3365	150170	153540	136500	149000	88.1	72.1	84.0
6	5	11320	6520	4870	173.4	35.7	17.22	1.52	28.34	96.96	94.09	2759	167190	169950	158200	164850	87.6	74.7	87.8
7	3	11150	6187	4960	173.4	33.9	17.36	2.66	28.55	97.06	90.17	1157	164945	166100	148350	161200	85.5	72.5	86.0
8	3	10970	6178	4840	170.2	49.6	17.36	2.66	28.44	97.15	88.62	654	161612	162270	143200	157700	86.9	74.4	86.6
9	2	11250	6560	4685	170.2	50.1	16.61	1.91	28.18	97.08	92.08	5830	164458	170290	151900	165300	87.8	72.8	86.3
10	1	12440	7060	5400	172.0	49.3	17.60	2.90	27.91	97.54	86.36	3133	185100	188230	161400	183600	89.5	72.0	83.3
11	2	8990	5195	3795	172.0	50.0	16.61	1.91	27.92	97.54	91.32	469	136850	137320	124890	133930	87.3	72.4	83.5
12	1	13240	7580	5610	172.6	48.8	17.06	2.36	27.99	98.32	85.06	6018	192290	198310	163500	194900	90.7	75.4	89.2
13	2	10240	6070	4220	172.0	47.1	16.80	2.10	27.98	98.50	91.05	825	156470	157230	142470	154500	88.2	72.8	83.8
14	2	11480	6140	5340	174.8	51.4	18.84	4.14	28.29	98.41	90.24	337	176210	176550	159010	173740	86.4	73.0	86.6
15	5	11504	6022	5468	170.8	48.1	19.45	4.75	27.51	97.83	95.15	—	167103	—	159000	—	91.8	78.2	93.5
16	7	11526	6314	5203	173.9	48.4	19.45	4.75	27.42	98.02	93.57	9033	167085	176718	157300	173200	92.9	78.6	91.5
17	5	11528	6084	5488	175.7	49.5	19.90	5.20	27.62	97.70	94.68	5111	179170	184301	169650	180100	86.4	73.6	86.7
18	6	10740	5916	4831	174.1	49.5	18.56	3.86	27.65	98.19	94.83	12554	149148	161702	141450	158750	85.7	72.8	83.6
19	6	14540	7860	6692	174.0	51.7	18.42	3.72	27.78	97.66	95.07	16404	201351	217755	191450	212700	90.9	72.2	88.2
20	4	14365	7373	6962	171.6	52.2	20.94	6.24	27.75	97.88	96.47	15423	196680	212103	189750	207750	90.3	72.6	93.7
21	6	10320	5632	4617	175.9	49.8	17.77	3.07	28.03	97.54	89.52	6486	144399	150885	129150	147100	87.8	72.5	84.4
23	6	13410	7460	5862	173.9	50.2	18.01	3.31	27.72	97.80	96.09	15760	195514	211274	188000	206800	91.1	73.0	87.0
24	6	12927	7033	5820	169.8	50.2	18.59	3.89	27.79	98.03	95.47	14439	173150	187589	165300	183950	89.8	73.3	86.8
25	6	9730	5142	4508	175.3	49.7	18.99	4.29	27.78	97.77	96.46	11189	134635	145824	129840	142600	88.8	72.3	82.8
26	6	11840	6470	5305	172.6	49.2	19.02	4.32	27.48	98.18	96.48	14090	161983	176073	156300	172900	88.2	73.1	84.9
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

TABLE 5 SERIES C

RESULTS									GUARANTEE & CALCULATED WATER RATES			CIRC WATER		WATER RATE, UNIT,	REMARKS	FORMULAE & NOTES
TEST	LOAD	WATER RATES (Dry Steam)														
		TURBINE ACTUAL	ENGINE ACTUAL	UNIT ACTUAL		UNIT Moist Corr	UNIT Total Corr		TURBINE Constant Nozzle Pr	ENGINE Constant Nozzle Pr	UNIT Constant Nozzle Pr	RATIO	TOTAL	EQUIVALENT I.H.P.		
	K.W.	Lbs per K.W.H	Do	Do		Do	Do.		Do.	Do	Do	C.W. Dry St.	Gals per Minute	Lbs per I.H.P.Hr. C.N.P.		
5	10220	30.98	22.48	14.57		14.0	13.53		28.42	26.03	14.42	89.0	26740	8.85	Varying Nozzle Pressure	$27 - \frac{17}{4 + [1 + (1-E)]5}$
6	11320	32.34	25.30	14.45		14.1	13.94		27.30	26.04	14.07	80.5	26920	8.68	Auxiliary Steam Included C.N.P.	
7	11150	30.42	26.05	14.49		13.85	13.90		27.22	26.07	14.10	78.3	25800	9.10	Constant Nozzle Pressure	$28 + 27 - (28.5 + 0$
8	10870	29.58	25.51	14.37		13.64	13.70		27.31	26.07	14.15	86.5	27900	8.76	Do	
9	11250	32.42	25.20	14.69		14.23	13.55		27.42	26.04	14.05	79.0	25980	9.03	Do.	
10	12440	29.85	26.01	14.76		13.95	13.36		27.00	26.08	13.88	93.5	30660	8.27	V.N.P.	
11	8930	32.91	25.79	14.89		14.36	13.78		28.29	26.99	15.10	94.5	25820	8.76	C.N.P.	
12	13240	29.15	25.71	14.72		13.90	13.39		26.90	26.46	13.90	76.5	30320	8.25	Do	
13	10240	33.76	25.52	15.13		14.51	13.99		27.83	26.10	14.41	96.0	30200	9.01	Do.	
14	11480	29.78	28.30	15.15		14.47	14.26		27.02	26.10	14.03	78.6	25000	9.14	V.N.P.	
15	11504	29.06	–	–		–	–		26.97	26.24	14.01	69.	23060	–	Aux. Included C.N.P.	
16	11526	30.22	27.42	15.02		14.64	13.86		27.10	26.12	14.01	82	27400	8.93	C.N.P.	
17	11528	30.30	29.70	15.68		15.20	14.32		26.96	26.20	14.01	81	25020	9.53	Aux. Included V.N.P.	
18	10740	29.26	26.84	14.78		14.41	13.56		27.31	26.30	14.22	98	29230	9.06	C.N.P.	
19	14540	28.60	27.05	14.62		14.30	13.58		26.63	26.69	13.80	66	26560	9.08	Do.	
20	14365	27.23	28.15	14.45		14.25	13.50		26.60	26.31	13.80	51	20050	9.05	V.N.P.	
21	10320	27.97	26.11	14.25		13.70	13.23		27.49	26.50	14.39	85	24520	8.52	C.N.P.	
23	13410	32.05	27.70	15.41		15.25	14.47		26.81	26.37	13.80	75.5	23520	9.81	Do.	
24	12927	28.40	26.14	14.22		14.0	14.29		26.82	26.16	13.81	78.5	27180	8.93	Do.	
25	9730	28.81	27.73	14.65		14.53	13.81		27.57	27.07	14.67	101.	27200	9.33	Do.	
26	11840	29.45	26.71	14.60		14.44	13.42		27.04	26.09	13.96	91.	24500	9.06	Do.	
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37

TABLE 6 SERIES C

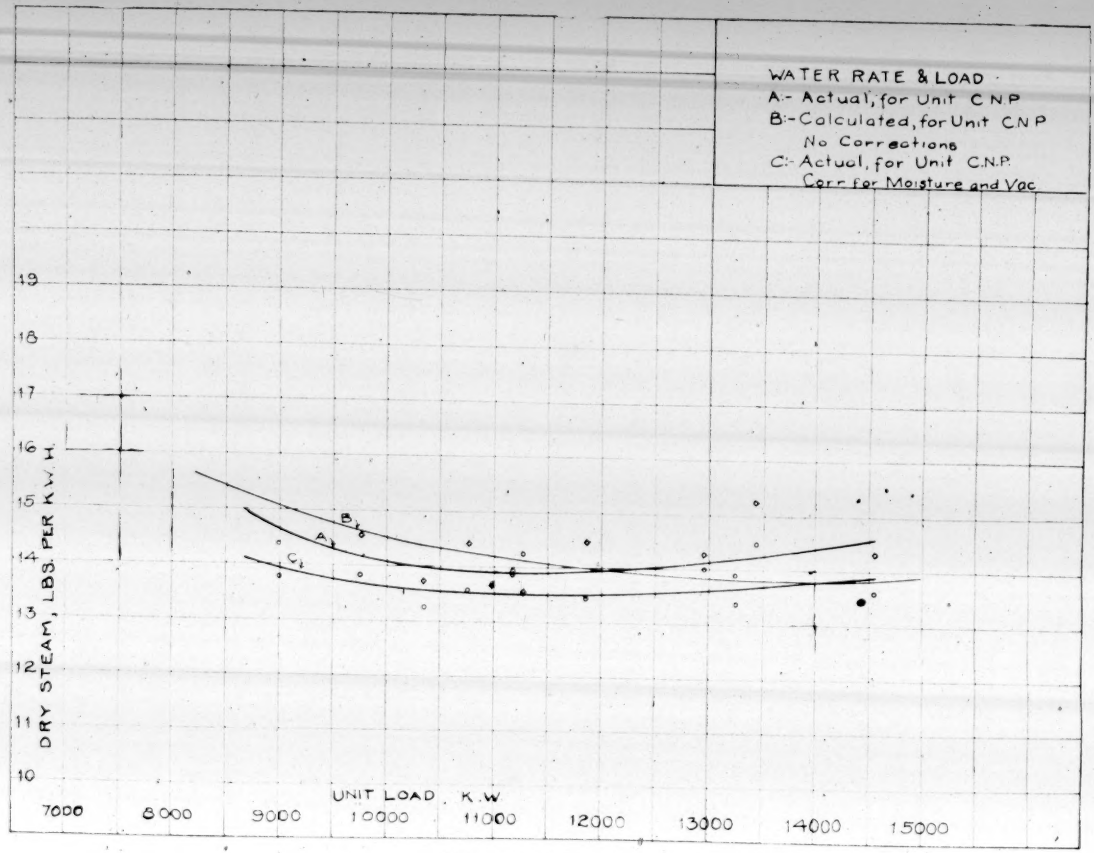


FIG. 11 SERIES C

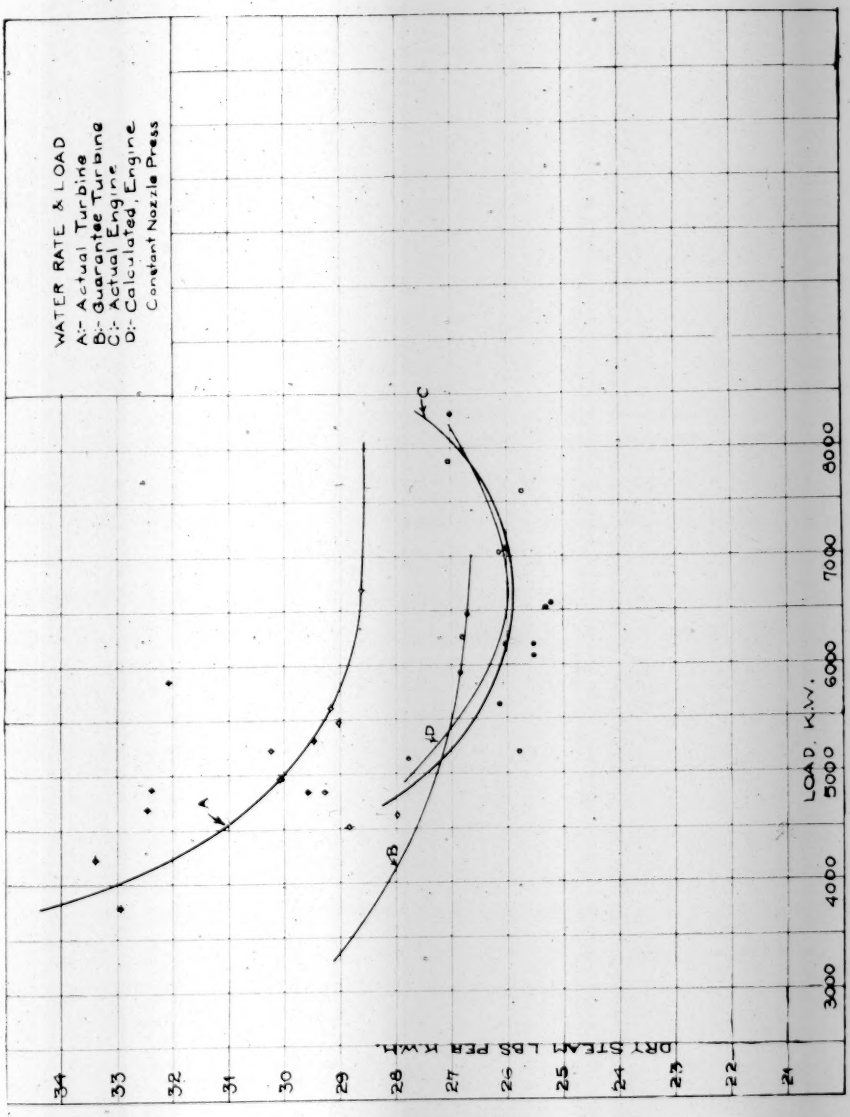


FIG. 11a SERIES C

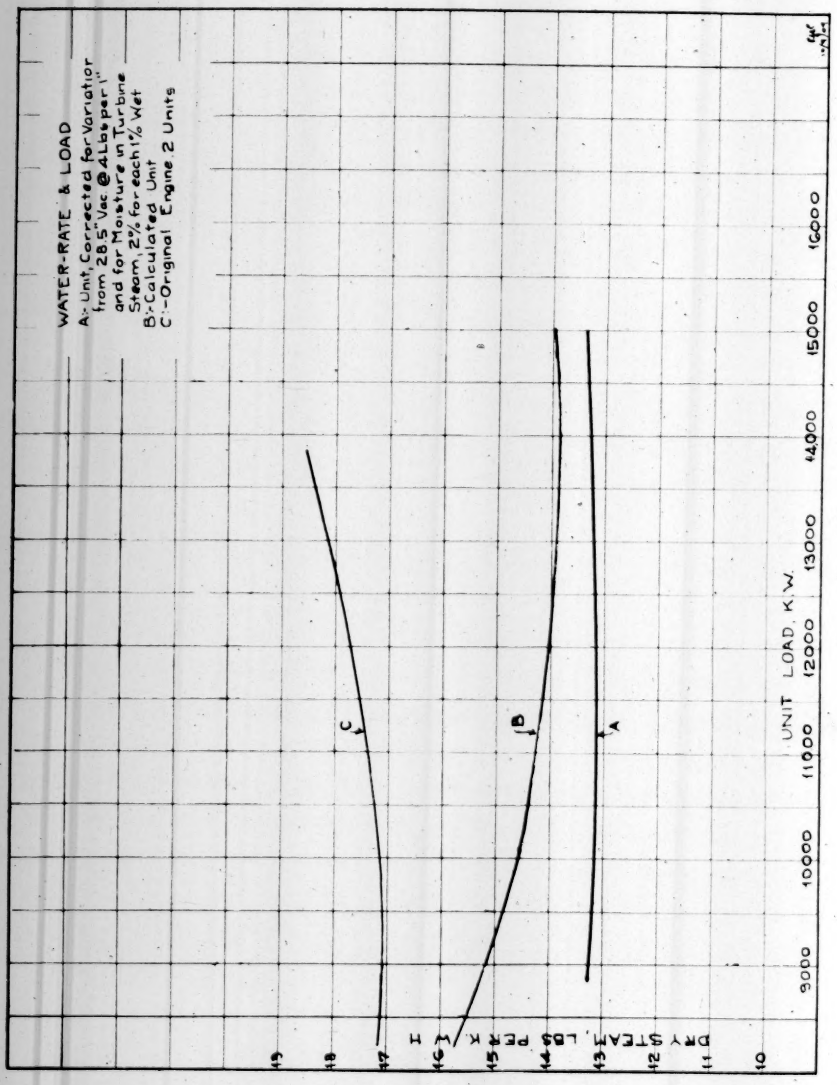


FIG. 11b SERIES C

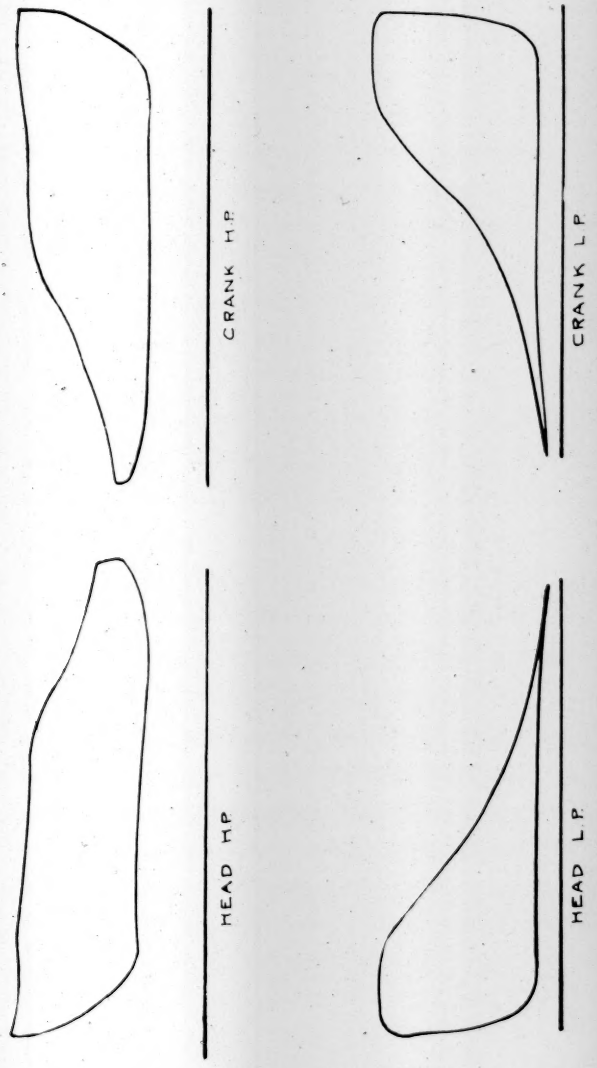


FIG. 12 SERIES C

TEST	DURATION	LOADS			PRESSURES					QUALITIES		WATER Lbs/Hr			DRY STEAM		TEMPERATURES		
		UNIT	ENG	TURB	HP STM	RECEIVERS	TURB STM	VACUUM	VAC 29.92" Barom Hg	HP STM	TURB STM	TOTAL CONDENSATION	TURB WATER	TOTAL WATER UNIT	TURBINE	ENG'S UNIT	COND HOT WELL °F	CIRC W INJECTION °F	CIRC W DISCH °F
	Hrs	KW	KW	KW	Lbs/□	Absolute	Do	Do		%	%								
27	6	9567	4875	4683	185.1	64.7	18.14	.70	28.50	99.0	93.4	8636	133840	142476	125000	141100	78.6	38.80	58.60
28	6	10527	5819	4714	189.8	64.9	16.93	.87	28.15	99.6	95.2	8570	146730	155300	139700	154700	80.4	39.53	67.04
29	2	11400	6410	5000	184.7	65.2	17.62	1.05	27.87	98.9	97.2	9601	162475	172076	158100	170300	81.3	37.46	67.77
30	4	11365	6590	4810	185.6	64.9	17.62	1.15	27.58	99.0	97.8	10088	161351	171439	157800	169700	84.5	38.20	73.80
31	6	12300	6930	5373	192.0	65.5	17.59	.90	28.12	99.3	97.8	11006	166820	177832	163200	176800	78.64	36.54	66.00
32	6	13160	7490	5717	193.4	66.3	17.66	.95	27.98	99.5	97.2	12142	179776	191918	174700	191000	75.34	35.76	69.72
33	4	16085	8505	7670	192.3	65.2	20.00	1.12	27.64	99.8	94.7	7312	247090	254402	234000	254000	86.44	35.05	73.41
34	6	14223	8183	6060	192.3	65.8	17.56	1.11	27.66	99.4	95.7	9361	206261	215622	197500	214300	85.06	34.88	74.30
35	4	13295	7783	5524	194.7	65.8	17.13	1.20	27.43	99.5	95.4	11145	187814	198359	178600	197500	90.85	35.22	76.39
36	5	12217	7169	5033	192.7	64.3	16.28	1.05	27.78	99.8	93.8	13017	165908	178925	155500	178700	89.42	34.66	70.76
37	6	10043	5813	4184	190.4	63.9	16.40	1.02	27.84	99.4	93.7	9823	140932	150755	132000	149800	91.80	36.67	70.72

TEST	ACTUAL WATER RATES			CORRECTED UNIT		IHP ENGINE			FACTOR IHP / KW
	ENG	TURB	UNIT	MOISTURE	MOIST & VAC	HP	LP	TOTAL	
27	28.94	27.65	14.75	14.30	14.30	3861	3502	7363	1.511
28	26.69	30.15	14.68	14.37	14.02	4138	4389	8497	1.461
29	26.57	31.62	14.94	14.74	14.11	4445	4712	9157	1.429
30	25.74	32.81	14.93	14.74	18.82	4477	4727	9204	1.397
31	25.49	30.38	14.36	14.22	13.74	4753	5045	9798	1.414
32	25.50	30.57	14.51	14.29	13.77	5092	5583	10675	1.425
33	29.86	30.80	15.79	15.32	13.46	5902	6229	12131	1.426
34	26.18	32.60	15.07	14.78	13.94	5585	6018	11603	1.417
35	25.38	32.34	14.85	14.56	13.55	5246	5082	10328	1.404
36	24.92	30.91	14.62	14.29	13.57	4873	5421	10294	1.435
37	25.77	31.54	14.93	14.60	13.94	4248	4312	8560	1.473

TABLE 7 SERIES D

NO. TEST	DATE 1910	DURATION Hrs	LOADS TOTAL UNIT KW	ENGINE K.W	TURBINE K.W	MN STEAM Abs Lbs/□"	MN STM Gge Lbs/□"	RECEIVERS Abs Lbs/□"	H.P. Gge Lbs/□"	L P SEPARATOR Abs Lbs/□"	L P SEP Gge Lbs/□"	L P SEP U Tube "Hg	VACUUM Hg Col "Hg	VAC Absolute Manom "Hg Ab	VAC Abs Lbs Abs	BAROMETER "Hg	STD VAC 29.92" Bur "Hg	CW PUMP SUCTION "Hg	CW PUMP DISCHARGE Gge Lbs/□"
38	Jan 11	5	16172	8384	7784	197.0	182.3	64.2	49.5	20.60	5.90	10.84	29.30	1.50	.74	30.63	28.42	12.7	12.0
39	11	5	13485	7798	5885	203.8	189.1	64.5	49.8	16.50	1.80	2.61	29.10	1.58	.78	30.59	28.34	12.2	12.9
40	12	5	13038	7314	5711	196.1	181.4	63.8	49.1	16.20	1.50	1.82	29.46	1.22	.60	30.61	28.72	11.0	12.8
41	12	5	12284	6938	5348	200.2	185.5	64.5	49.8	16.10	1.40	2.18	29.32	1.31	.64	30.57	28.69	12.6	12.1
42	13	5	11252	6248	4938	197.0	182.3	64.0	49.3	16.24	1.54	2.20	29.41	1.32	.65	30.65	28.60	9.9	14.3
43	13	5	10476	5824	4602	198.0	183.3	63.8	49.1	16.20	1.50	2.00	29.23	1.46	.72	30.58	28.46	12.6	12.8
44	14	5	9408	4940	4426	198.8	184.1	63.8	49.1	16.10	1.40	2.28	28.47	.93	.46	30.31	28.99	9.5	11.6
45	14	13/4	9712	5816	3709	198.2	183.5	64.3	49.6	10.50		7.48	28.96	1.22	.60	30.21	28.70	11.6	11.6
46	15	1/2	12700	7180	5640	198.5	183.8	62.6	47.9	12.96		-2.78	28.45	1.03	.51	30.32	28.82	13.75	9.5
47	15	1/2	11940	7060	4780	195.3	180.6	62.6	47.9	12.35		-1.80	29.72	1.03	.51	30.32	28.89	12.9	9.9
48	15	3	9306	5865	3323	196.3	181.5	63.8 46.3	49.1 31.6	9.65		-10.49	29.13	1.20	.59	30.33	28.72	12.0	10.6
49	15	1	10940	6640	4300	194.9	180.2	49.3	35.6	11.65		-6.62	29.19	1.13	.56	30.32	28.79	12.1	10.9
50	15	4	15438	8163	7260	192.0	177.3	59.0	44.3	17.80	3.10	3.54	29.23	1.13	.56	30.32	28.79	14.6	10.4
51	17	3	11240	6753	4376	194.0	179.3	55.0	40.3	11.50		-6.71	29.25	1.19	.58	30.38	28.73	11.5	9.9
52	17	3	7200	4743	2400	196.6	181.8	41.5	26.8	7.97		-14.92	29.07	1.23	.63	30.29	28.63	10.6	10.7
53	17	3	11827	7070	4834	199.0	184.3	52.9	38.2	12.75		4.58	29.10	1.25	.61	30.26	28.67	13.2	10.1
54	20	3	14173	7820	6283	193.4	178.6	55.7	40.9	15.18	.48	1.04	29.31	.93	.46	30.03	28.93	10.1	9.5
55	20	3	8347	5403	2910	197.4	182.7	43.0	28.3	8.21		-13.48	28.90	1.15	.57	29.97	28.77	12.4	9.0
56	20	3	13033	7457	5550	197.2	182.5	54.3	39.6	14.09		-1.75	29.01	1.01	.50	29.90	28.91	13.2	9.4
57	27	3	14580	7960	6583	195.7	179.2	59.6	45.1	15.57	.87	+3.04	28.85	.85	.42	29.49	29.07	10.3	8.8
58	27	3	6673	4420	2213	197.7	183.2	40.1	25.6	7.08		-15.14	28.48	.98	.48	29.48	28.94	12.6	8.6
59	27	3	10007	6194	3804	199.1	184.6	47.3	32.0	10.35		-8.53	28.55	.94	.46	29.50	28.98	14.3	8.7
60	28	3	11820	6923	4860	195.1	180.5	51.6	36.9	12.10		-4.98	28.96	.87	.43	29.79	29.05	10.7	10.4
61	28	3	11480	6587	4893	196.8	182.2	51.4	36.7	12.34		-4.46	28.88	1.00	.49	29.79	28.92	12.4	10.2
62	28	3	15860	8440	7410	195.0	180.4	63.4	48.8	17.84	3.14	7.60	28.73	1.15	.58	29.79	28.73	13.5	9.9

TABLE 8 SERIES E AND F

NO. TEST	LOAD	HP THROTTLING CALRIM				#1 SEPARATING			#2 SEPARATING			#1 THROTTLING				#2 THROTTLING		
		AV MN STM. TEMP	CAL. DISCH. TEMP	CAL DISCH PRESS. Gauge "Hg	QUAL	MOISTURE	FLOW	QUAL	MOISTURE	FLOW	QUAL	STM TEMP	DISCH TEMP	DISCH PRESS Vacuum	QUAL.	DISCH TEMP	DISCH PRESS Vacuum	QUAL.
	KW	°F	°F	"Hg	%	Lbs	Lbs.	%	Lbs	Lbs.	%	°F	°F	"Hg	%	°F	"Hg	%
38	16172	380.6	312.1	18.27	99.5	11.55	153.43	92.9				229.2	198.4	17.76	99.2			
39	13485	383.4	282.0	25.68	97.9	10.45	117.59	91.8				217.6	184.2	20.31	98.8			
40	13038	380.2	302.9	21.81	99.2	10.10	119.41	92.2				216.7	182.0	20.74	98.8			
41	12284	381.9	297.5	19.80	98.9	9.88	119.93	92.4				216.3	180.3	20.55	98.7			
42	11252	380.6	294.8	20.77	98.7	9.73	120.16	92.6	1.42	18.77	93.0	216.7	181.5	20.60	98.7	164.0	26.12	98.1
43	10476	381.0	291.8	20.42	98.5	8.86	111.94	92.6	3.18	46.47	93.6	216.7	182.9	21.50	98.8	168.9	26.23	98.4
44	9408	381.3	297.9	21.78	98.7	8.05	99.50	92.5	1.08	18.90	94.6	216.4	179.3	21.55	98.6	177.0	25.71	98.5
45	9712	381.1	294.8	21.92	98.7	1.10	14.10	92.8	.79	11.95	93.8	195.4	172.5	23.70	99.2	159.5	27.37	98.6
46	12700	381.2	296.7	21.40	98.8	.43	10.60	96.1	.16	4.00	96.2	210.2	170.3	21.30	98.4	163.9	26.40	98.3
47	11940	379.9	304.0	20.63	99.1	.29	9.10	96.9	.16	3.60	95.8	203.3	176.0	22.48	98.9	165.7	26.72	98.6
48	9306	380.3	290.5	21.18	98.6	2.43	42.25	94.6	1.22	16.88	93.3	191.8	171.2	24.29	99.3	156.9	27.42	98.6
49	10540	379.7	295.0	21.05	98.9	.74	16.77	95.7	.41	6.90	94.4	200.3	178.3	22.62	99.3	167.3	26.76	98.7
50	15458	378.5	305.6	19.77	99.4	2.84	70.70	96.2	1.27	41.56	97.0	221.4	189.4	19.89	98.8	182.5	25.40	98.6
51	11240	379.4	292.6	21.93	98.6	2.04	51.67	96.2	1.15	19.96	94.5	199.8	174.8	22.68	99.0	165.0	27.04	99.1
52	7200	380.4	288.8	20.71	98.4	2.04	36.77	94.7	.93	14.05	93.7	182.4	163.0	25.21	99.3	148.0	27.75	98.6
53	11527	381.4	294.4	20.64	98.6	1.79	56.20	95.3	1.11	21.66	95.1	204.7	177.0	21.96	99.0	168.8	26.73	98.7
54	14173	379.1	296.9	22.41	98.9	2.13	56.70	96.3				213.3	191.4	19.92	99.4			
55	8347	380.8	292.9	20.87	98.6	1.57	38.91	96.1				184.2	165.2	24.20	99.3			
56	13033	380.7	298.2	20.25	98.7	1.63	61.64	97.4				209.7	184.9	20.81	99.1			
57	14580	379.2	298.8	21.75	99.0	2.06	70.87	97.2				215.3	188.9	18.77	99.0			
58	6673	380.9	298.4	21.80	99.0	1.79	33.30	94.9				178.4	161.1	24.41	99.4			
59	10007	381.5	287.0	21.53	98.2	2.62	47.12	94.7				194.8	171.1	22.70	99.2			
60	11820	379.8	295.9	21.34	99.0	1.56	54.77	97.2				202.4	175.0	21.67	99.0			
61	11480	380.5	302.8	21.00	99.1	1.55	55.79	97.3				203.3	178.4	21.57	99.0			
62	15860	379.7	299.7	20.63	99.0	2.19	80.02	97.3				221.9	197.6	17.87	99.3			

TABLE 9 SERIES E AND F

NO TEST	THOMAS CALORIMETER					#1 COMB. QUAL	#2 COMB. QUAL	AVGE QUAL	EXHAUST FROM ENGINE								QUAL by Separator Water & Turb Stm Qual.		
	WATT HRS	STM TEMP	CAL DISCH TEMP	CAL DISCH WATER	QUAL				SEPARATING CAL			THROTTLING CAL				COMB QUAL			
									MOISTURE	FLOW	QUAL.	STM. TEMP	CAL. DISCH TEMP	CAL. DISCH PRESS	QUAL				
	WH	°F	°F	Lbs	%	%	%	%	Lbs.	Lbs.	%	°F	°F	Vac "Hg	%	%	%		
38	6600	229.2	414.6	93.90	84.1	92.2		90.2											
39	5623	217.6	430.6	84.10	86.3	90.7		89.4											
40	4758	216.7	429.9	93.60	92.4	91.1		91.5											
41	3242	216.3	412.7	70.20	93.2	91.2		91.9											
42	4268	216.7	426.8	110.20	94.4	91.4	91.2	93.0											
43	5000	216.7	408.3	116.50	94.3	91.5	92.1	92.6											
44	4575	216.4	424.6	88.80	91.9	91.2	93.2	92.1											
45	1519	195.4	445.2	30.90	94.9	92.0	92.5	93.1											
46	500	210.2	356.9	20.40	98.5	94.6	94.6	95.9											
47	350	203.3	454.2	27.40	95.6	95.8	94.5	95.3											
48	2100	191.8	420.0	37.92	91.7	93.9	92.0	92.5											
49						95.0	93.2	94.1											
50	2377	221.4	346.5	81.70	95.8	95.0	94.4	95.1											
51	2100	199.8	420.7	47.70	95.4	95.2	93.6	94.7											
52	2300	182.4	395.5	58.40	96.5	94.0	92.4	94.3											
53	2500	204.7	433.2	59.00	96.2	94.3	93.8	94.8											
54	650	213.3	276.7	44.05	98.0	95.7		96.9	2.53	26.90	91.4	213.8	180.5	23.29	98.7	90.2	89.6		
55	600	184.2	293.6	28.10	97.4	95.4		96.4	2.05	15.17	88.1	185.6	148.7	26.71	98.5	86.8	90.2		
56	600	209.7	268.5	44.40	98.1	96.5		97.3	2.53	21.70	89.5	209.5	167.7	25.41	98.6	88.2	90.3		
57	600	215.3	260.8	56.10	98.4	96.2		97.3	1.92	21.40	91.8	216.2	172.1	25.16	98.4	90.3	89.3		
58	450	178.4	267.7	24.90	97.0	94.4		95.7	1.88	17.12	90.7	177.9	148.3	25.80	98.8	89.0	89.7		
59	600	194.8	265.5	32.80	97.2	94.0		95.6	2.28	15.72	87.3	195.3	154.0	26.02	98.5	86.0	89.8		
60	600	202.4	274.2	39.90	98.2	96.3		97.3	2.49	19.17	88.6	203.4	163.4	25.76	98.5	87.3	90.3		
61	600	203.3	272.8	41.40	98.3	96.3		97.3	2.34	16.95	87.9	204.1	160.1	26.07	98.3	86.4	91.2		
62	700	221.9	274.3	55.40	98.1	96.6		97.4	2.11	24.65	92.1	222.8	178.4	24.73	98.5	90.7	89.8		

TABLE 10 SERIES E AND F

TEST	WEST MN STM.	EAST MN STM	AVGE MN STM	WEST RECEIVER	EAST REC	AVGE REC	EAST ENG EXH	EAST SEPARATOR INLET	SEPARATOR OUTLET	TURBINE BOWL	CONDENSER	HOT WELL WATER	CIRC WATER INJECTION	CIRC WATER DISCHARGE
	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F	°F
38	381.0	380.2	380.6	297.0	297.4	297.2	230.5	230.1	229.2	228.5	90.90	71.20	37.66	57.28
39	384.1	382.8	383.4	297.3	297.4	297.4	218.7		217.6	217.0	94.60	76.23	39.85	62.51
40	380.3	380.1	380.2	296.1	297.5	296.8	218.0	217.6	216.7	216.1	84.45	70.97	32.03	51.84
41	382.4	381.4	381.9	297.0	297.7	297.3	217.5	217.2	216.3	216.3	87.17	73.41	33.95	56.76
42	380.2	380.5	380.6	296.9	297.0	297.0	218.6	218.6	216.9	216.9	87.18	75.25	31.82	56.67
43	380.6	381.3	381.0	296.8	296.6	296.7	217.9		216.7	216.3	88.32	80.17	32.75	57.14
44	380.3	382.2	381.3	296.9	296.5	296.7	217.6		216.4	216.1	73.87	59.42	31.63	41.98
45	380.3	381.8	381.1	296.8	297.7	297.3	208.2		195.4	196.7	86.72	66.20	32.22	43.97
46	379.7	382.7	381.2	295.0	296.0	295.5	209.0		210.2	208.0	77.20	63.70	40.20	53.10
47	378.0	380.8	379.9	295.3	296.0	295.6	205.0		203.3	204.0	80.00	63.00	36.00	46.65
48	379.6	381.0	380.3	297.1 276.3	296.4 275.8	296.7 276.1	193.7 190.5		191.8	1925 189.4	84.86	60.58	32.50	42.06
49	377.8	381.6	379.7	275.6	280.4	280.0	202.0		200.3	201.0	83.50	62.60	31.38	53.86
50	376.7	380.2	378.5	291.5	291.5	291.5	222.6		221.4	221.0	82.23	65.69	31.51	50.08
51	379.0	379.8	379.4	287.2	286.8	287.0	203.4		199.8	199.8	83.16	65.18	37.50	43.10
52	379.7	381.0	380.4	268.9	270.2	269.6	183.8		182.4	180.8	85.70	58.15	31.47	35.81
53	380.5	382.3	381.4	285.5	283.2	284.4	205.7		204.7	204.6	83.65	65.65	31.46	45.37
54	376.3	381.8	379.1	287.1	288.7	287.9	215.6		213.3	213.3	81.20	57.26	33.54	47.77
55	378.0	383.5	381.8	271.8	271.7	271.7	181.0		184.2	183.8	81.00	58.64	33.08	41.30
56	378.4	383.0	380.7	285.8	286.5	286.2	209.3		208.7	207.6	74.70	60.72	33.40	50.10
57	377.0	381.4	379.2	293.0	291.6	292.3	217.5		214.9	215.5	67.41	53.21	33.28	47.60
58	375.4	382.5	380.9	267.5	267.9	267.7	177.4		177.4	176.3	78.20	53.85	33.18	39.46
59	380.0	383.0	381.5	277.5	277.4	277.5	195.7		194.8	194.1	78.30	55.12	33.40	45.66
60	377.9	381.7	379.8	283.2	283.0	283.1	204.4		202.4	202.4	74.04	59.66	33.25	46.00
61	378.5	382.4	380.5	283.0	282.5	282.8	209.0		208.3	208.2	77.18	61.74	33.06	47.23
62	377.5	381.8	379.7	296.3	296.3	296.3	223.9		221.9	221.8	82.42	62.79	32.64	56.00

TABLE 11 SERIES E AND F

NO	LOAD	WATER PER HOUR								WATER RATES					I.H.P.			
		TURB. WAT. W.C.H.D.	TURB. WAT. VENTURI	SEP. & TRAPS W.C.H.D.	SEP. WATER	TRAPS VENTURI	TOT. ENG. WATER	DRY STM ENG.	DRY STM TURB	ACT. UNIT	ACT. ENG.	ACT. TURB.	CORR UNIT MOIST ONLY	CORR UNIT TOTAL CORR	AV. H.P.	AV. L.P.	TOTAL	FACTOR
	K.W.	LBS PER HR.	LBS PER HR.	LBS PER HR.	LBS PER HR.	LBS PER HR.	LBS PER HR.	LBS PER HR.	LBS PER HR.	LBS PER K.W. HR.	LBS PER K.W. HR.	LBS PER K.W. HR.	LBS PER K.W. HR.	LBS PER K.W. HR.	I.H.P.	I.H.P.	I.H.P.	
38	16172	237480		7425	7175	250	244905	243700	234200	15.07	29.54	27.51	14.40	14.10	5640	6117	11757	1.404
39	13485	187193		9883	5881	4002	197836	193000	187400	14.38	24.76	28.36	13.48	13.10	5104	5847	10951	1.404
40	13038	170661		12251	6281	5980	182932	181500	156200	13.92	24.78	27.35	13.44	13.42	4931	5650	10581	1.447
41	12284	160229		12004	3628	8436	172493	170400	147800	13.88	24.57	27.51	13.39	13.28	4800	5306	10106	1.457
42	11252	147142		10927	2607	8320	158069	156100	136900	13.87	24.99	27.72	13.54	13.42	4250	4330	8580	1.374
43	10470	138700		9939	1801	7138	147152	145000	128500	13.85	24.90	27.91	13.47	13.21	4227	4280	8507	1.460
44	9403	122689		8387	237	8150	130816	129400	113000	13.15	26.19	25.53	13.32	13.59	3771	3490	7261	1.470
45	9712	121670		13160	4910	8250	135050	134300	113500	13.78	22.23	30.09	13.47	13.45	3813	4367	8186	1.385
46	12700	160980		18874	11242	7632	174834	117100	154400	13.19	24.75	27.38	13.62	13.77	4994	6313	11307	1.575
47	11948	142746		17365	8935	8450	160125	158300	136800	13.30	22.49	28.45	13.15	13.31	4675	5736	10411	1.475
48	9306	114372		12555	4744	7811	126927	125100	105800	13.44	21.34	31.84	13.25	13.25	4129	4321	8450	1.441
49	10940	134785		16565	8257	8308	151550	149700	126600	13.69	22.40	29.50	13.39	13.46	5039	4545	9584	1.444
50	15498	202656		19161	10661	8500	221817	220400	192900	14.22	26.99	26.55	13.96	14.03	5784	5825	11609	1.421
51	11240	133462		16689	8319	8370	150151	148100	126500	13.19	21.95	28.89	13.04	13.04	4585	5244	9829	1.456
52	7200	89158		10861	7170	3691	100019	98400	84080	13.67	20.75	35.04	13.52	13.43	3662	3478	7140	1.505
53	11927	143897		17901	8164	9737	161396	159500	136500	13.38	22.57	28.22	13.13	13.08	4935	4897	9832	1.400
54	14173	176565		19180	12930	6250	195740	193600	171050	13.66	24.15	27.22	13.54	13.81	5430	5370	10800	1.400
55	8347	99210		13733	6183	7550	112943	111400	95620	13.34	20.60	32.85	13.23	13.28	3907	3732	7639	1.425
56	13033	158112		18849	11159	7690	176161	174700	153850	13.40	23.43	27.72	13.28	13.47	5115	5120	10235	1.373
57	14580	182508		20011	14741	5270	202599	200700	177600	13.75	25.19	26.95	13.65	14.00	5376	5673	11049	1.388
58	6673	81533		11225	4900	6325	92998	91800	78000	13.76	20.78	35.27	13.65	13.87	3282	3170	6452	1.460
59	10007	120863		14578	6478	8100	135441	133050	115600	13.30	21.48	30.38	13.13	13.39	4452	4254	8746	1.413
60	11820	141930		17833	9873	7960	159763	158200	136100	13.38	22.84	28.41	13.28	13.61	5108	4796	9904	1.431
61	11480	143928		17101	8791	8310	161059	159600	141500	13.92	24.45	24.22	13.75	13.95	4728	4594	9322	1.414
62	15860	206603		19762	15705	4057	226365	224200	201300	14.14	26.58	26.56	13.99	13.99	5750	6538	12288	1.456

TABLE 12 SERIES E AND F

NO. TEST	TOT. LOAD	B.T.U. DISTRIBUTION : UNIT IS 1000000 B.T.U. SUPPLIED TO UNIT		SUPPLIED TO TURB ONLY		ENG. K.W. OUTPUT		TURB. K.W. OUTPUT		TOTAL K.W. OUTPUT		TO CONDENSER		TO HOT WELL		LOST BY RADIA ETC.	
	KW	BTU	%	BTU	%	BTU	%	BTU	%	BTU	%	BTU	%	BTU	%	BTU	%
38	16172	292.0	100	252.5	86.5	28.61	9.8	26.58	9.1	55.19	18.9	216.6	74.2	9.31	3.2	10.89	3.7
39	13485	232.6		196.6	84.6	26.36	11.3	19.88	8.6	46.27	19.9	168.4	72.4	8.28	3.6	9.64	4.1
40	13038	218.0		182.5	83.7	24.97	11.5	19.49	8.9	44.46	20.4	156.4	71.7	6.65	3.1	10.53	4.8
41	12284	204.7		171.8	83.9	23.67	11.6	18.25	8.9	41.92	20.5	146.9	71.7	6.64	3.2	9.23	4.5
42	11252	187.7		159.5	85.0	21.35	11.4	16.95	9.0	38.37	20.5	136.2	72.5	6.36	3.4	6.85	3.7
43	10476	174.5		149.8	85.9	19.93	11.4	15.76	9.0	35.68	20.5	127.3	73.0	6.69	3.8	4.77	2.7
44	9408	155.8		131.9	84.6	16.87	10.8	15.12	9.7	32.09	20.6	113.4	72.7	3.36	2.2	7.03	4.5
45	9712																
46	12700																
47	11940																
48	9306	150.5		122.3	81.3	20.14	13.4	11.46	7.6	31.61	21.0	107.6	71.5	3.27	2.2	8.06	5.4
49	10940																
50	15498	264.2		224.2	84.8	27.95	10.6	24.85	9.4	52.56	19.9	192.5	72.8	6.83	2.6	12.05	4.6
51	11240	178.0		146.0	81.8	23.16	13.0	15.05	8.4	37.85	21.3	126.5	70.9	4.43	2.5	8.84	5.0
52	7200	118.4		96.41	81.4	16.25	13.7	8.26	7.0	24.37	20.6	85.8	72.5	2.33	2.0	5.74	4.8
53	11927	191.8		157.8	82.3	24.16	12.6	16.53	8.6	40.66	21.2	136.4	71.2	4.84	2.5	9.84	5.1
54	14173	232.4		197.8	85.4	26.76	11.5	21.53	9.1	48.29	20.4	171.8	72.4	4.46	1.9	7.84	3.3
55	8347	133.8		109.55	81.9	18.48	13.8	9.97	7.5	28.45	21.3	97.9	73.2	2.64	2.0	5.77	4.3
56	13033	210.0		175.5	83.6	25.46	12.1	18.97	9.0	44.43	21.2	151.9	72.3	4.54	2.2	9.04	4.3
57	14580	240.7		205.4	85.4	27.20	11.3	22.51	9.4	49.74	20.7	179.0	74.4	3.87	1.6	8.10	3.4
58	6673	110.4		89.25	80.9	15.13	13.7	7.59	6.9	22.73	20.6	79.8	72.4	1.78	1.6	6.02	5.5
59	10007	160.0		133.6	83.2	21.13	13.2	12.99	8.1	34.12	21.3	116.7	72.9	3.28	2.1	5.87	3.7
60	11820	189.8		158.9	83.7	23.67	12.5	16.62	8.8	40.29	21.2	138.4	72.9	3.92	2.1	7.23	3.8
61	11480	191.8		161.5	84.2	22.47	11.7	16.70	8.7	39.17	20.4	140.5	73.3	4.28	2.2	7.83	4.1
62	15860	269.2		232.2	86.3	28.82	10.7	25.31	9.4	54.11	20.1	200.5	74.5	6.36	2.4	8.18	3.0

TABLE 13 SERIES E AND F

EFFICIENCIES											HEAT TO COND			REMARKS
NO. TEST	LOAD UNIT	RANKINE EFFICIENCIES			THERM EFFIC REF'D TO RANKINE			THERMAL EFF RECOV HW WATER			RATIO CW/ST	BTU per □' Sec	BT U' per □' Sec per °Rise	
		ENG. %	TURB %	UNIT %	ENG %	TURB %	UNIT %	ENG %	TURB %	UNIT %				
38	16172	16.7	18.2	30.1	70.3	60.0	65.0	11.7	10.9	19.5	53.5	2.58	.0594	CNP Auxiliaries Exhaust to Heaters
39	13485	16.8	16.8	29.1	81.5	63.5	70.5	13.7	10.7	20.5	48.2	1.99	.0459	Do
40	13038	17.8	18.4	30.8	76.9	60.0	68.5	13.7	11.0	21.1	52.9	1.86	.0437	Do.
41	12284	17.6	17.7	30.4	78.5	62.3	69.7	13.8	11.0	21.2	46.4	1.77	.0428	Do.
42	11252	17.4	17.8	30.3	76.4	61.8	70.1	13.6	11.0	21.2	42.7	1.65	.0384	Do
43	10476	17.3	17.7	30.2	78.9	60.5	70.7	13.6	11.4	21.4	44.2	1.53	.0345	Do.
44	9408	17.6	18.8	29.4	73.2	62.5	71.8	12.9	11.7	21.1	107.7	1.37	.0369	Do
48	9306	20.5	15.6	30.5	74.9	61.2	71.0	15.4	9.5	21.7	11.8	1.26	.0266	V.N.P
51	11240	19.7	16.4	30.8	76.7	53.6	72.0	15.1	10.5	22.2	15.0	1.28	.0298	Do.
54	14173	18.2	18.7	31.2	74.5	59.1	68.1	13.6	11.1	21.2	77.1	2.08	.0512	Do
55	8347	21.2	17.5	30.5	74.6	52.6	71.5	15.8	9.2	21.8	11.2	0.92	.0210	Do
56	13033	18.2	18.4	31.0	78.5	59.4	69.0	14.2	10.9	21.7	63.4	1.87	.0566	Do
57	14580	18.0	19.5	32.2	74.0	57.0	65.4	13.6	11.1	21.0	77.5	2.16	.0800	Do.
58	6673	21.3	14.6	31.4	73.2	59.0	67.0	15.6	8.6	21.0	15.3	2.55	.0608	Do.
59	10007	19.5	16.7	31.3	78.5	60.0	69.8	15.3	10.0	21.8	1.08	1.41	.0336	Do
60	11820	19.5	20.2	32.2	74.8	52.9	67.6	14.5	10.7	21.8	82.9	1.67	.0485	Do
61	11480	19.6	17.6	31.4	69.8	60.4	66.9	13.7	10.7	21.0	108	2.40	.0885	Do Auxiliaries exhaust into Separator
62	15860	17.2	18.7	30.0	74.0	59.4	68.9	12.7	11.1	20.7	49.0	2.52	.0670	Do " " " Heaters

TABLE 14 SERIES E AND F

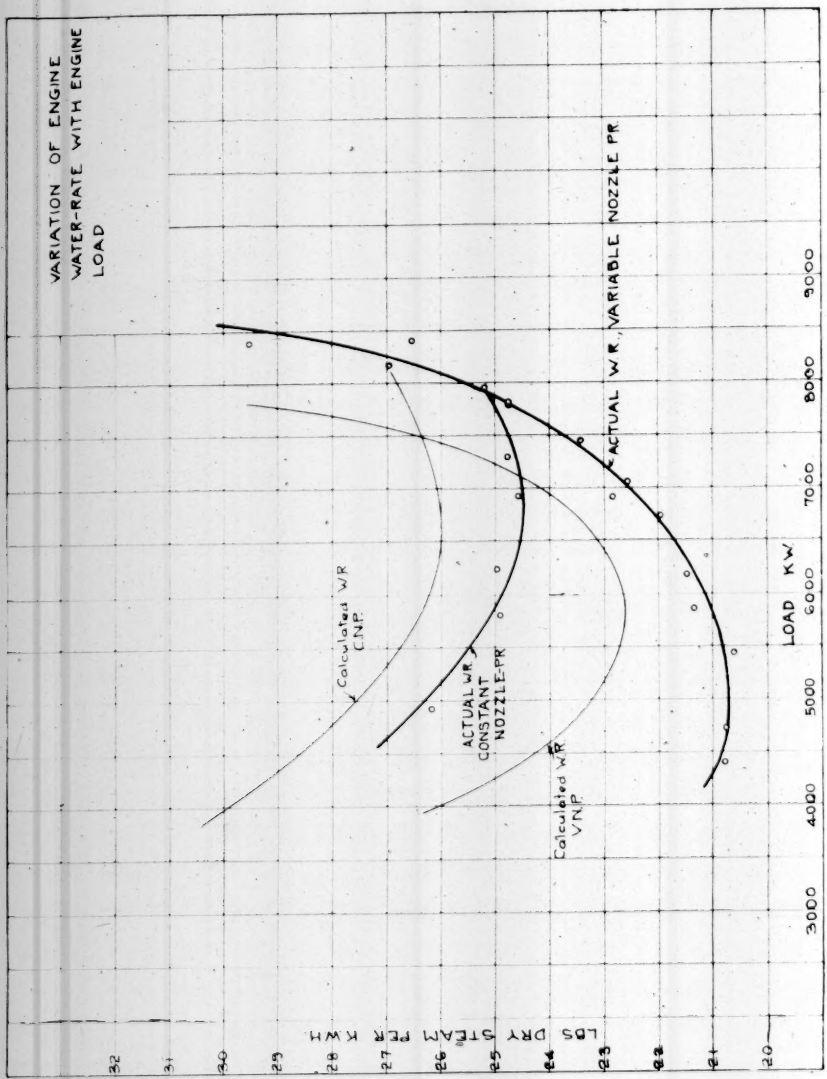


FIG. 13 SERIES E AND F

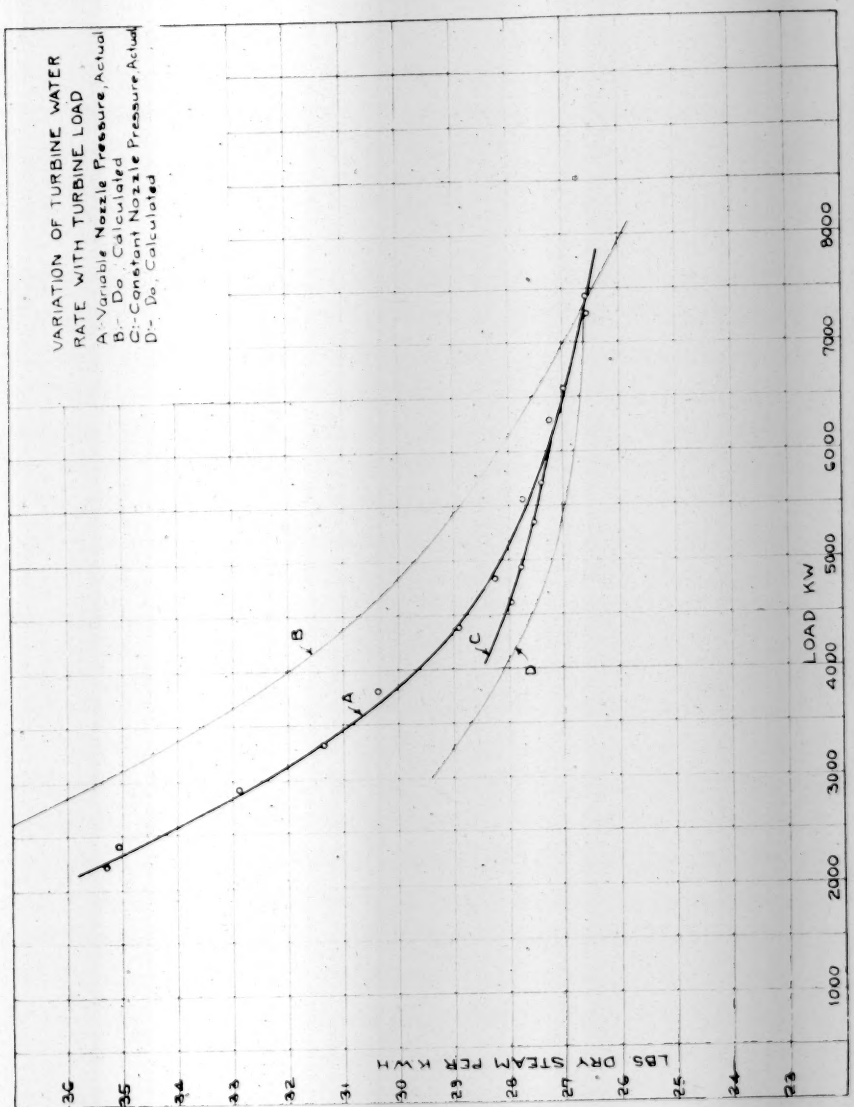


FIG. 14 SERIES E AND F

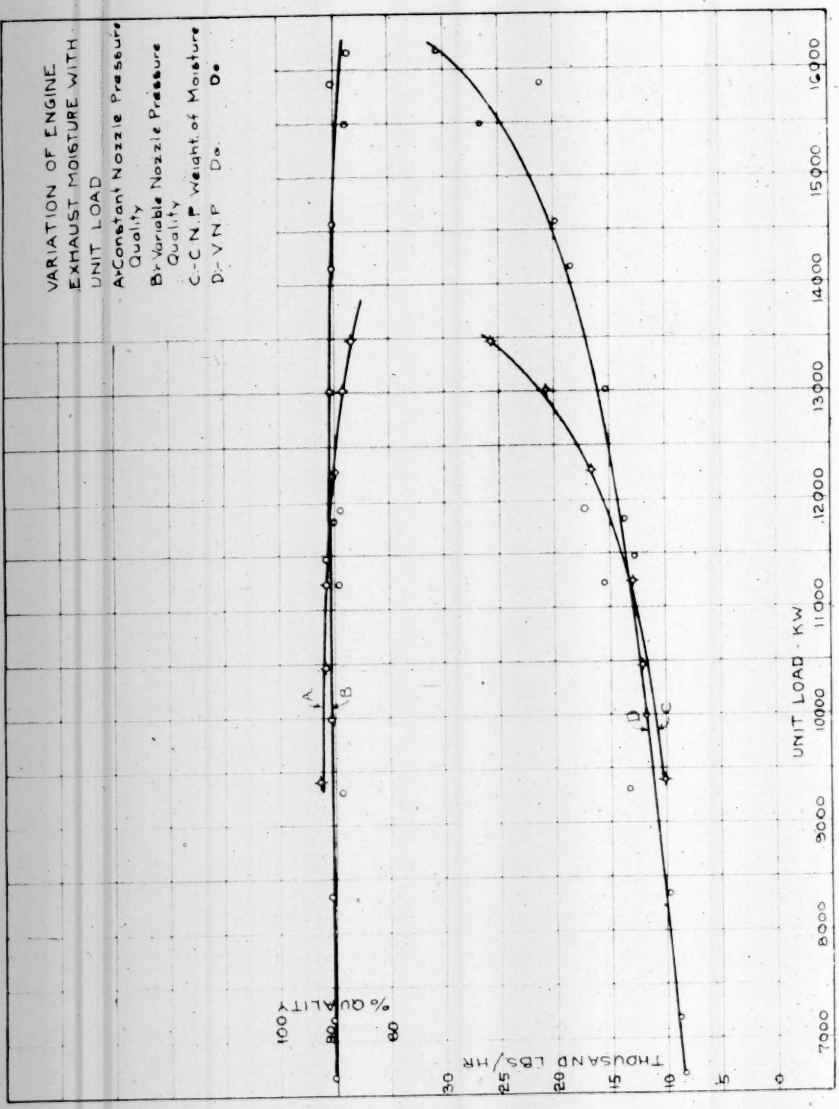


Fig. 15 Series E and F

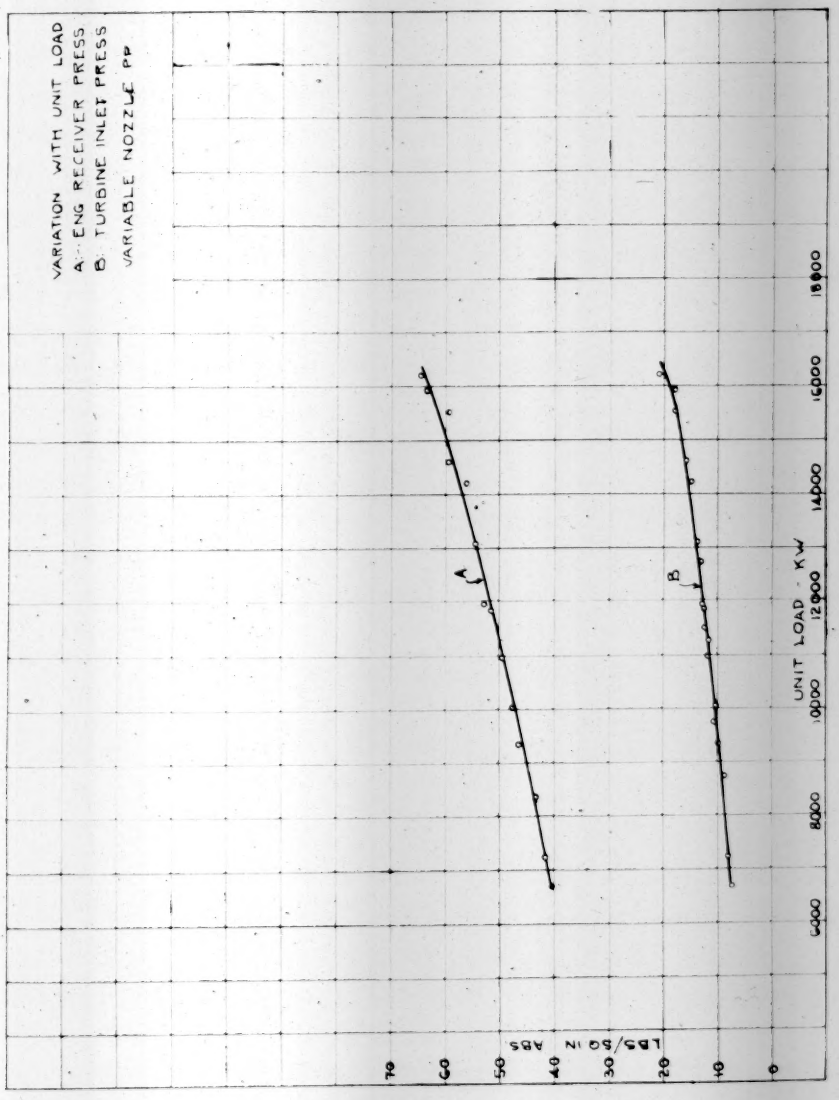


FIG. 16 SERIES E AND F

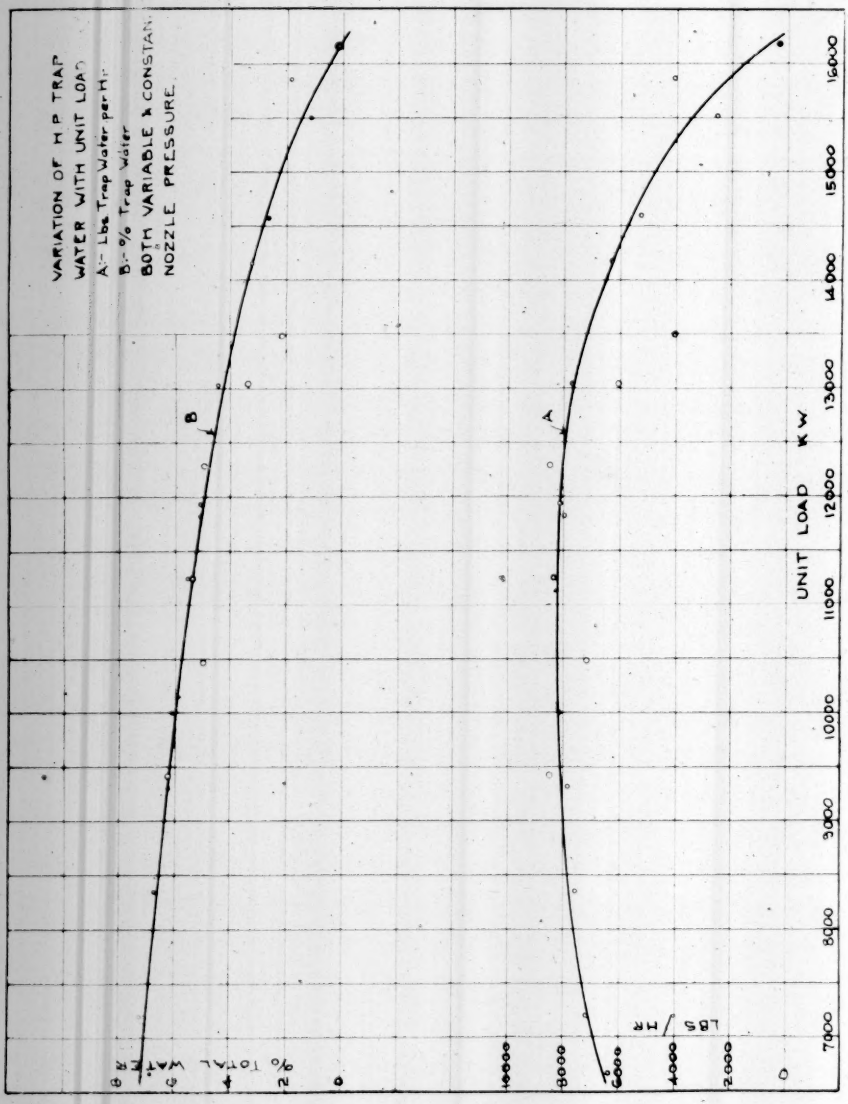


FIG. 17 SERIES E AND F

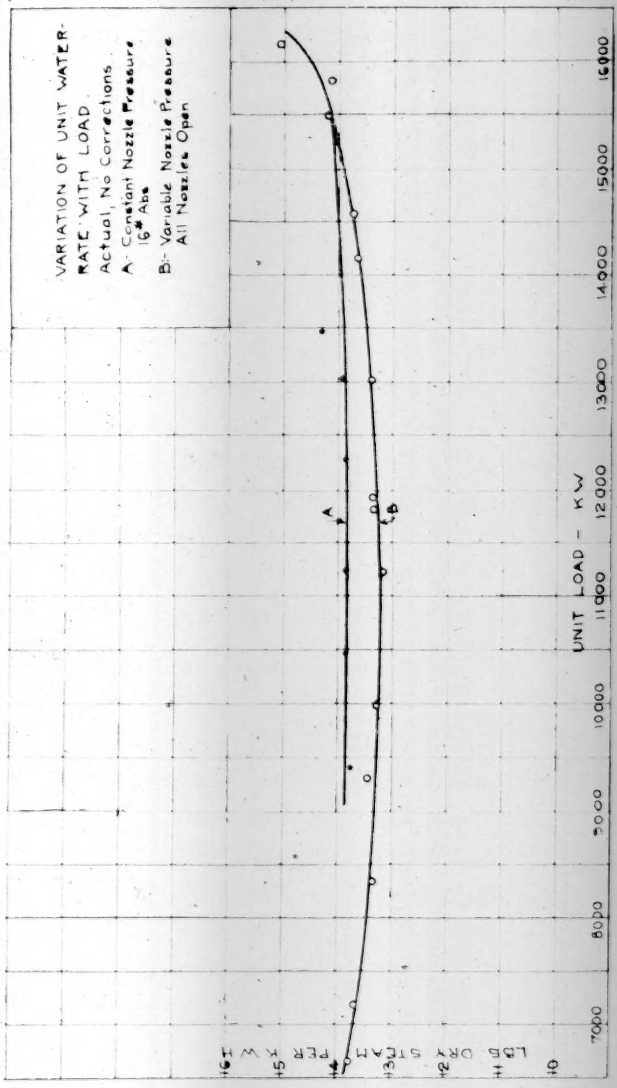


FIG. 18 SERIES E AND F

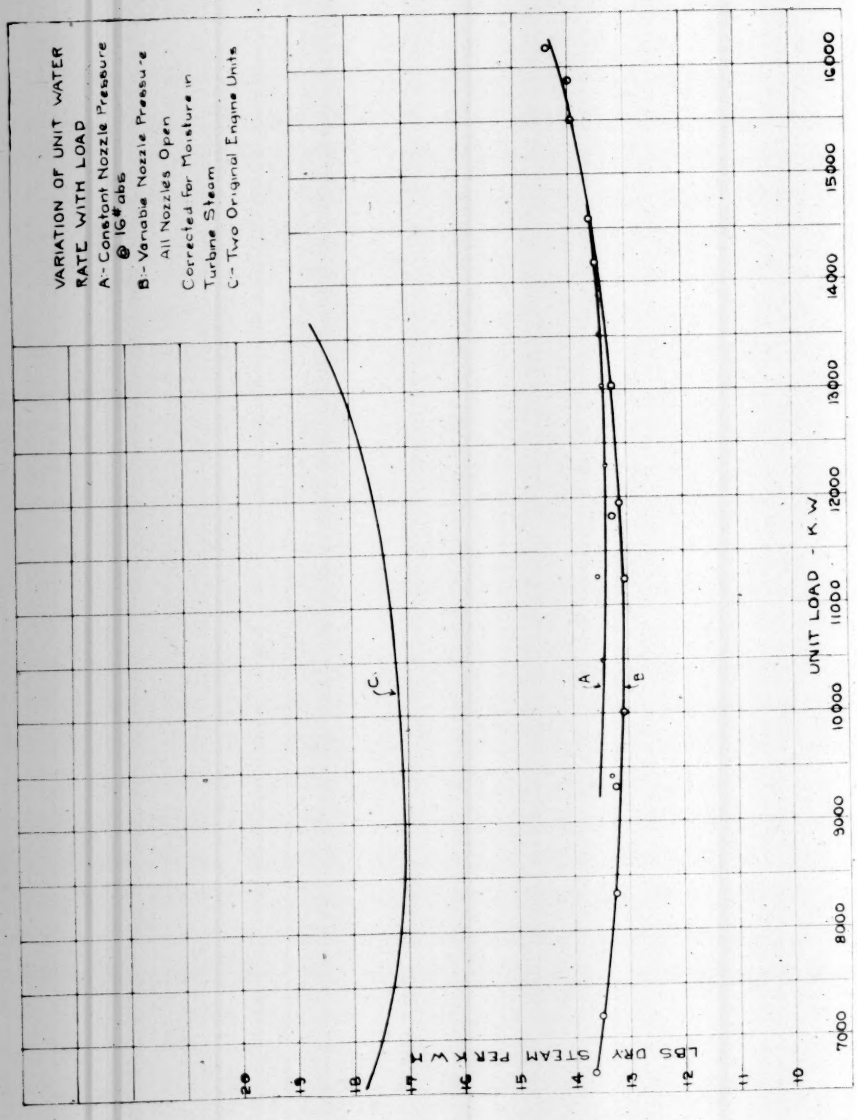


FIG. 19 SERIES E AND F

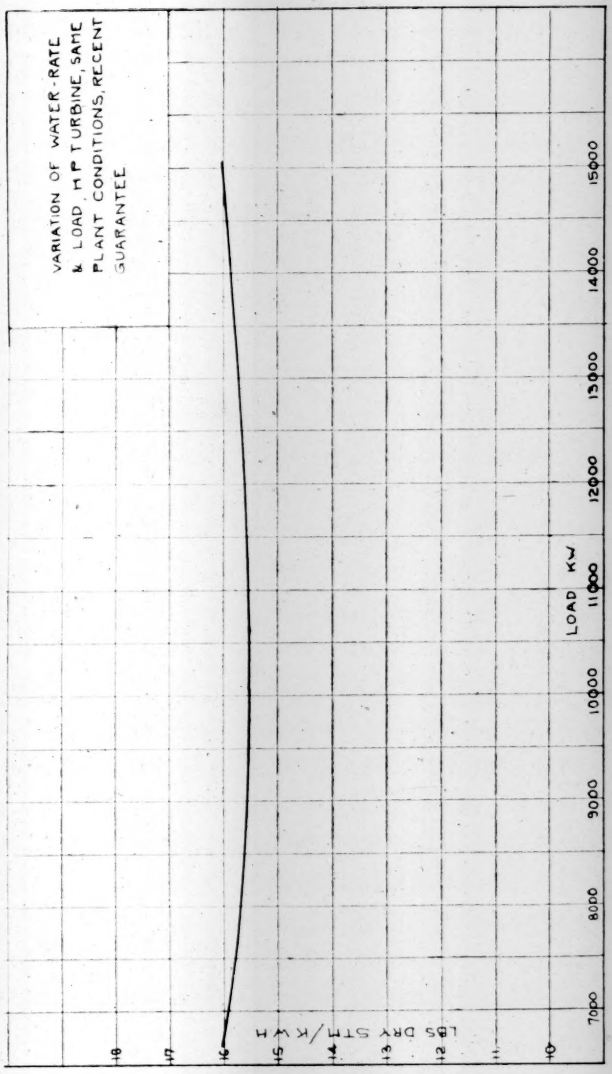


FIG. 19a SERIES E AND F

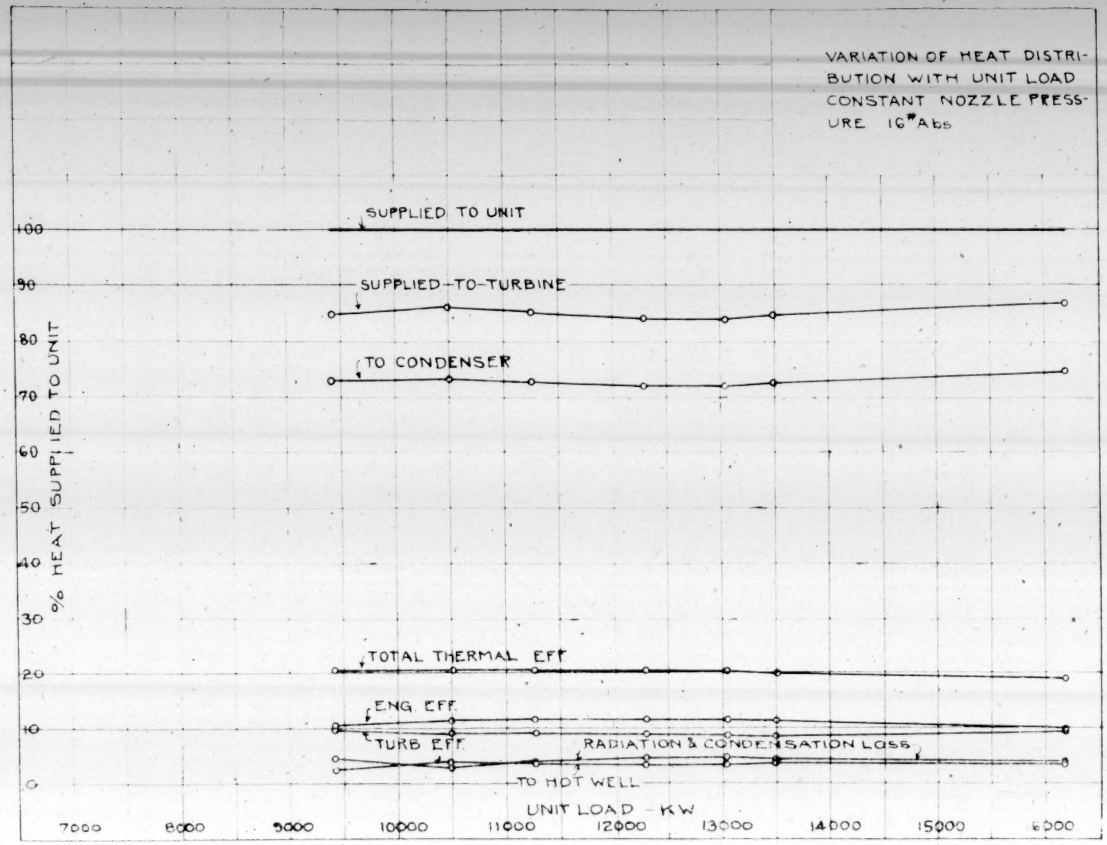


FIG. 20 SERIES E

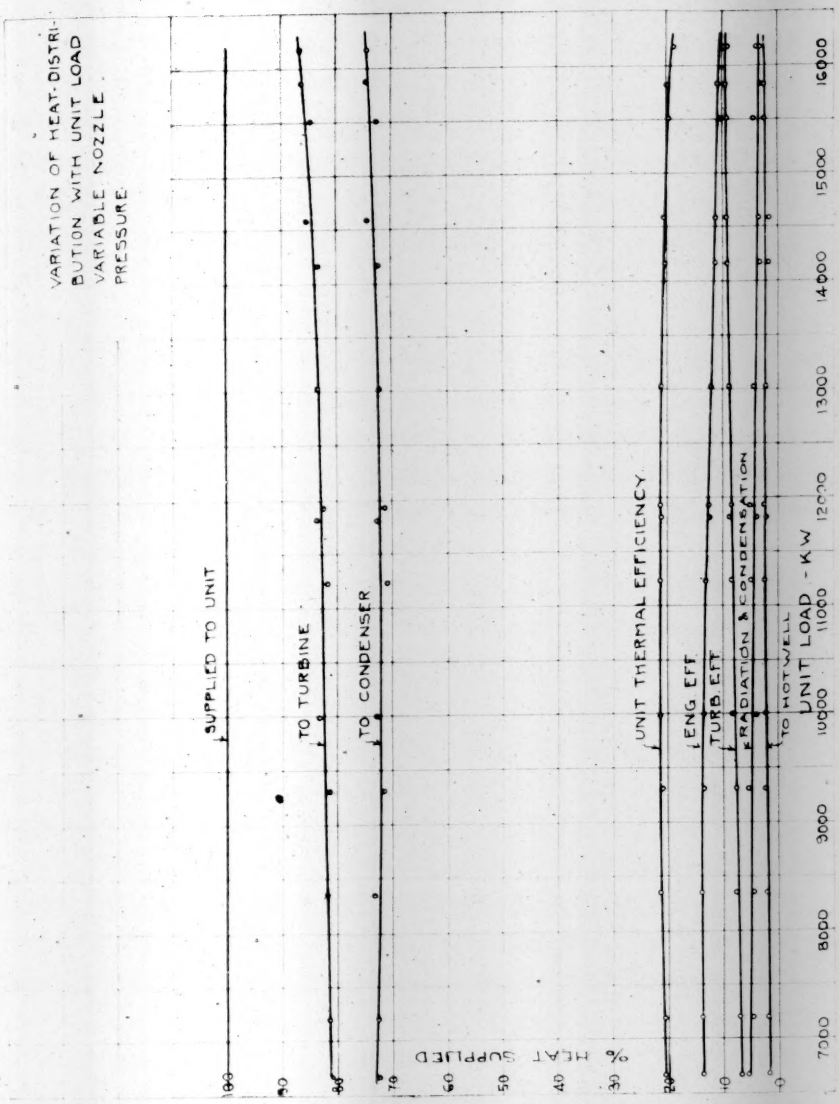


FIG. 21 SERIES F

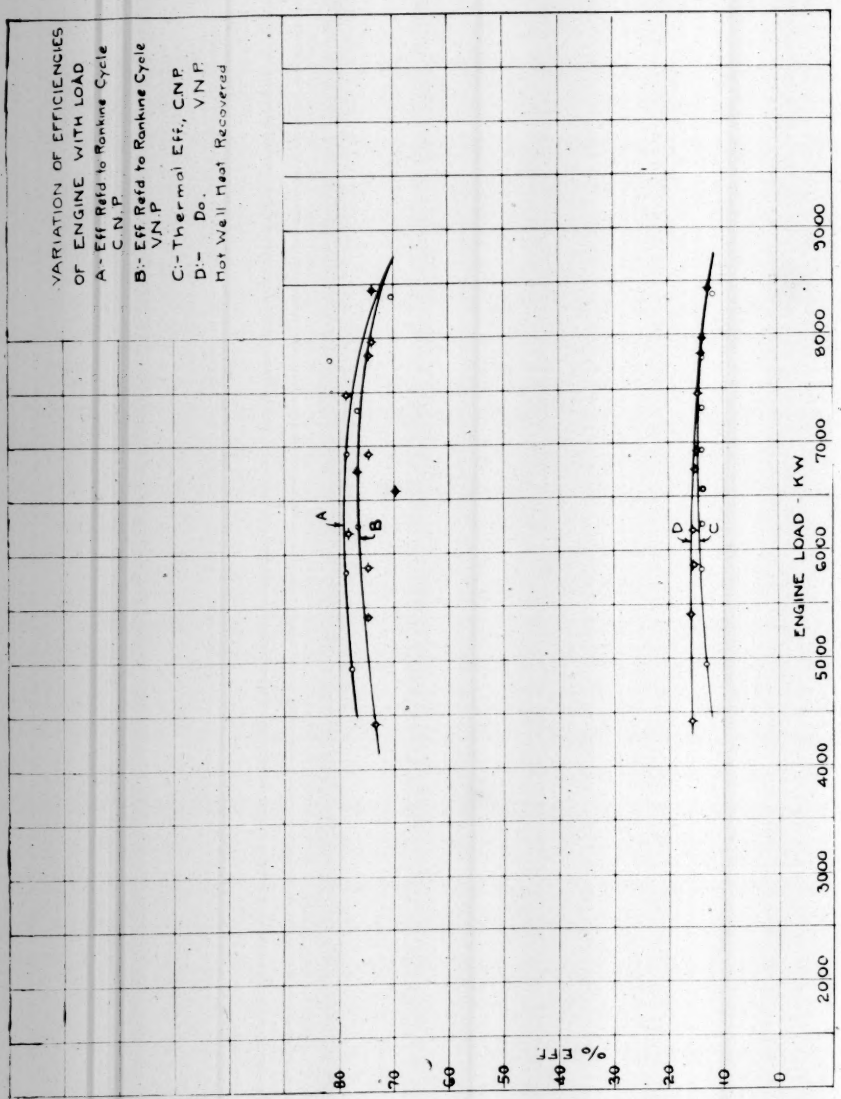


FIG. 22 SERIES E AND F

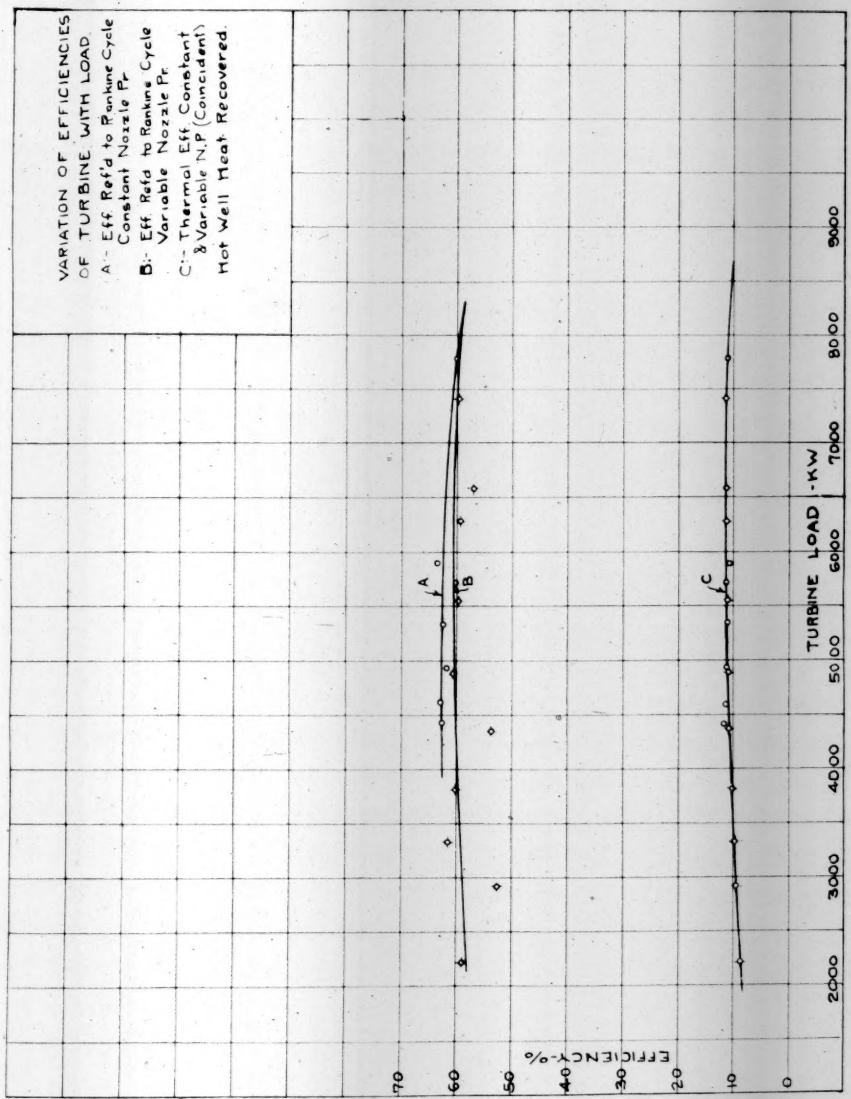

VARIATION OF EFFICIENCIES OF TURBINE WITH LOAD
A - Eff Ref'd to Rankine Cycle Constant Nozzle Pr.
B - Eff Ref'd to Rankine Cycle Variable Nozzle Pr.
C - Thermal Eff. Constant & Variable N.P. (Coincident) Hot Well Heat Recovered.
EFFICIENCY-%
TURBINE LOAD - KW
A
B
C

FIG. 23 SERIES E AND F

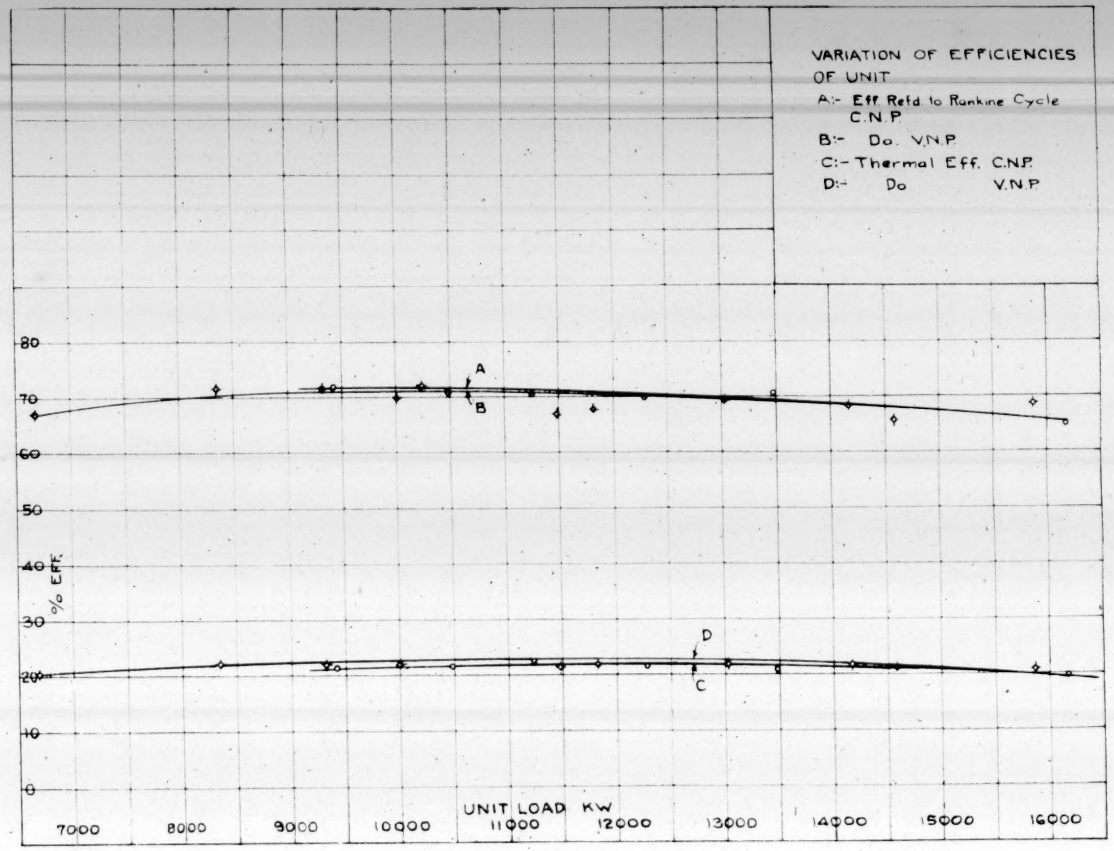


FIG. 24 SERIES E AND F

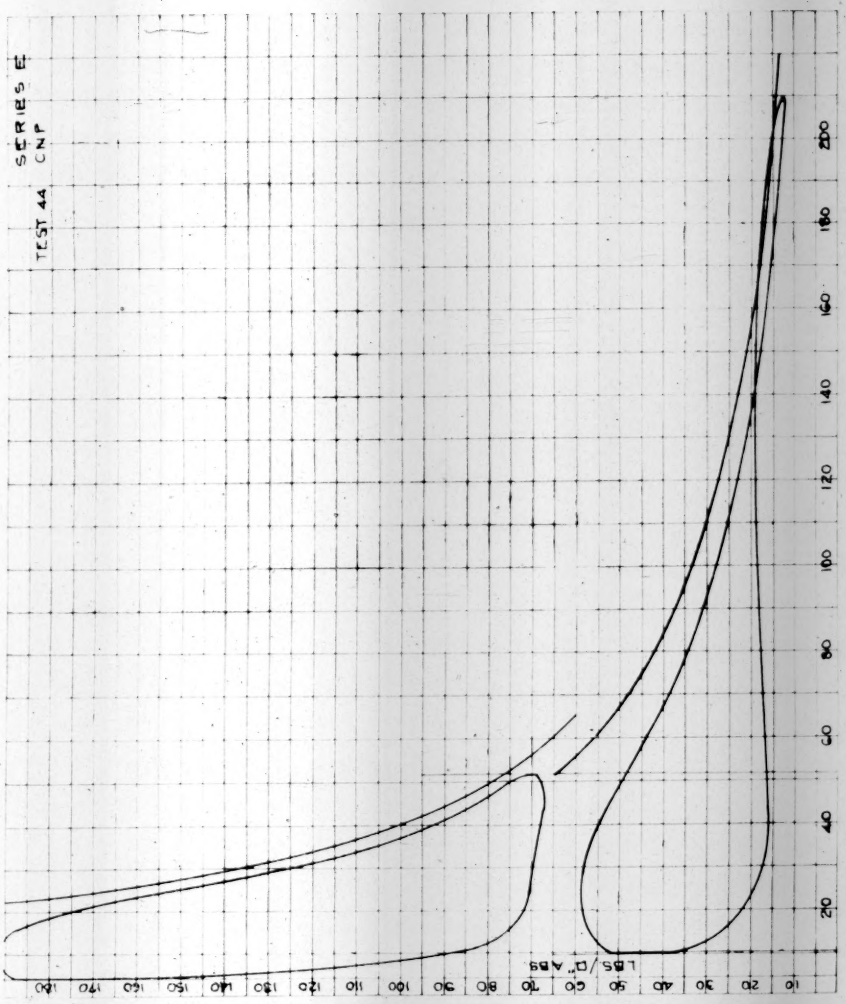


FIG. 25 SERIES E, TEST 44

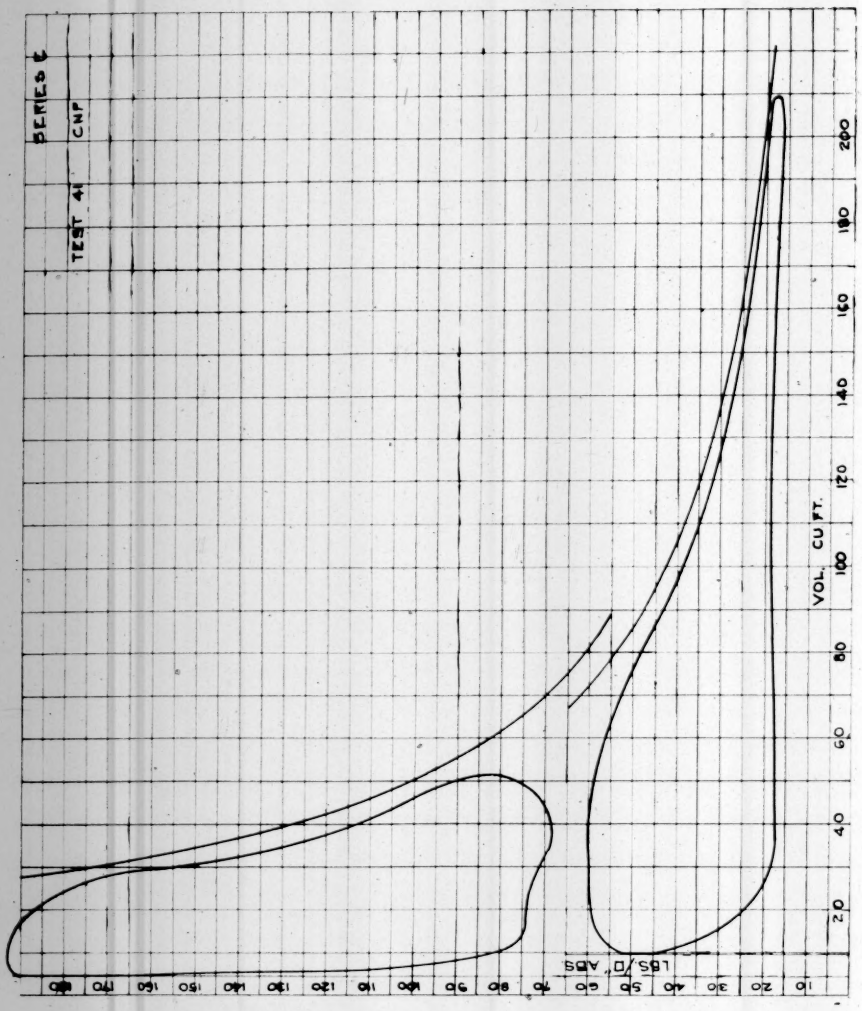


FIG. 26 SERIES E, TEST 41

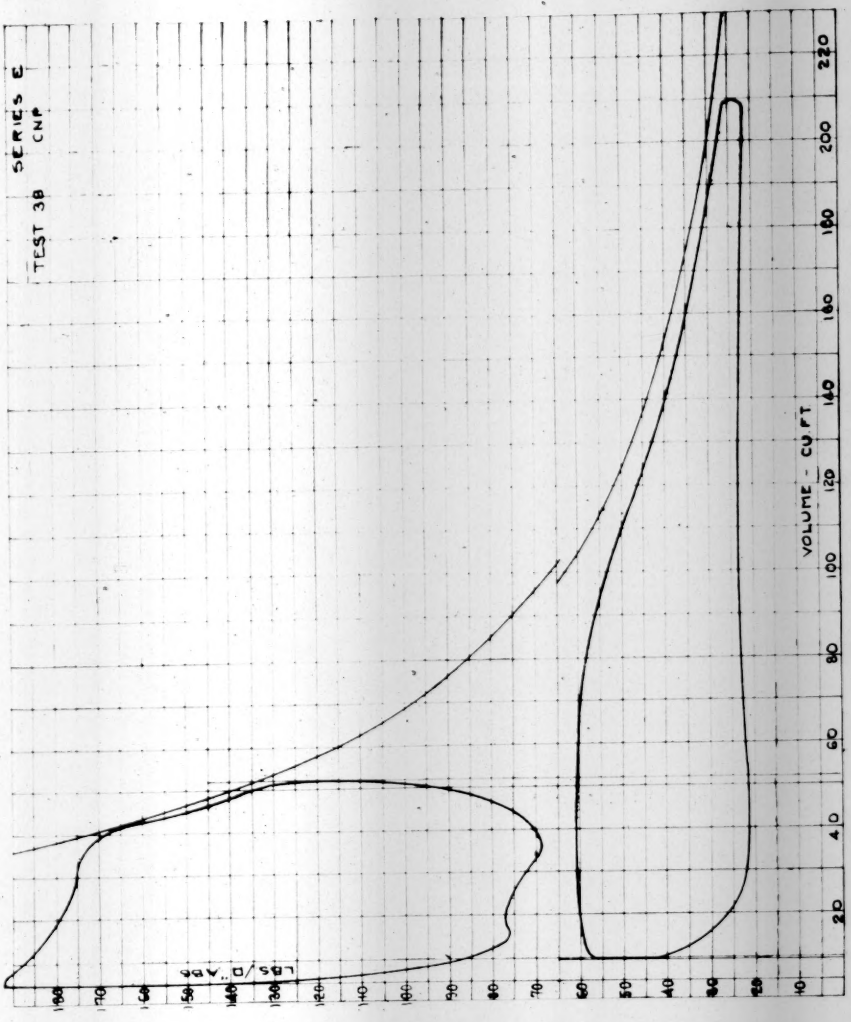


FIG. 27 SERIES E, TEST 38

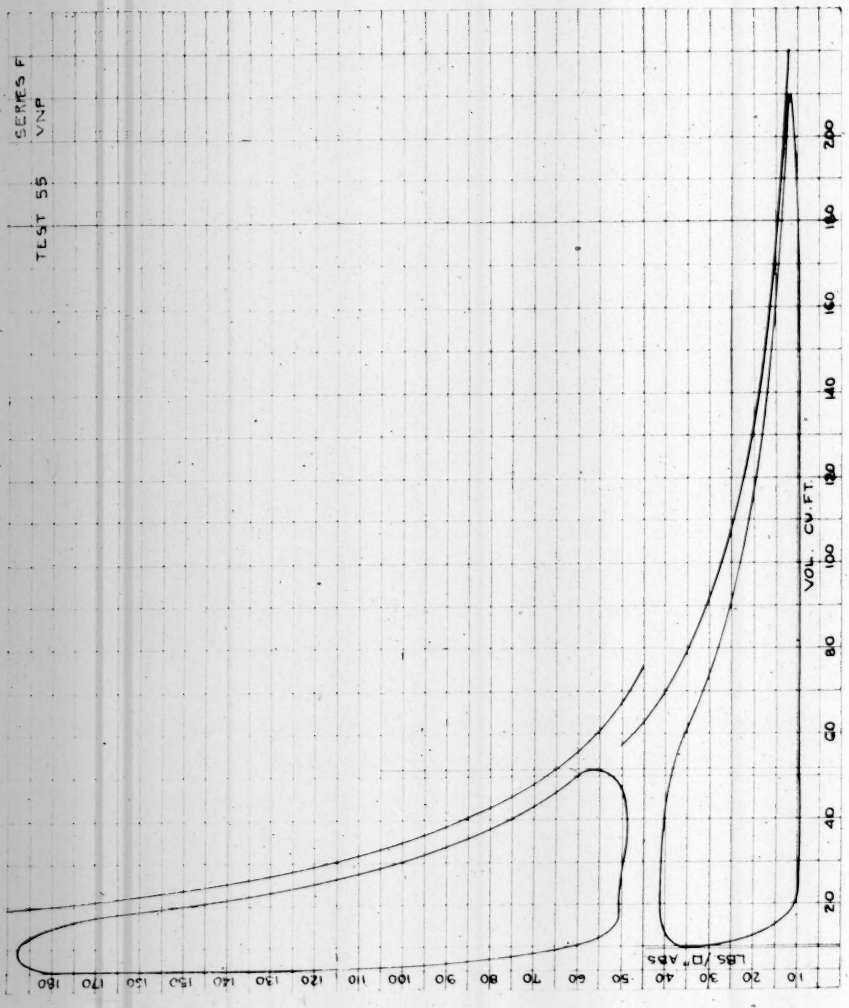


FIG. 28 SERIES F, TEST 55

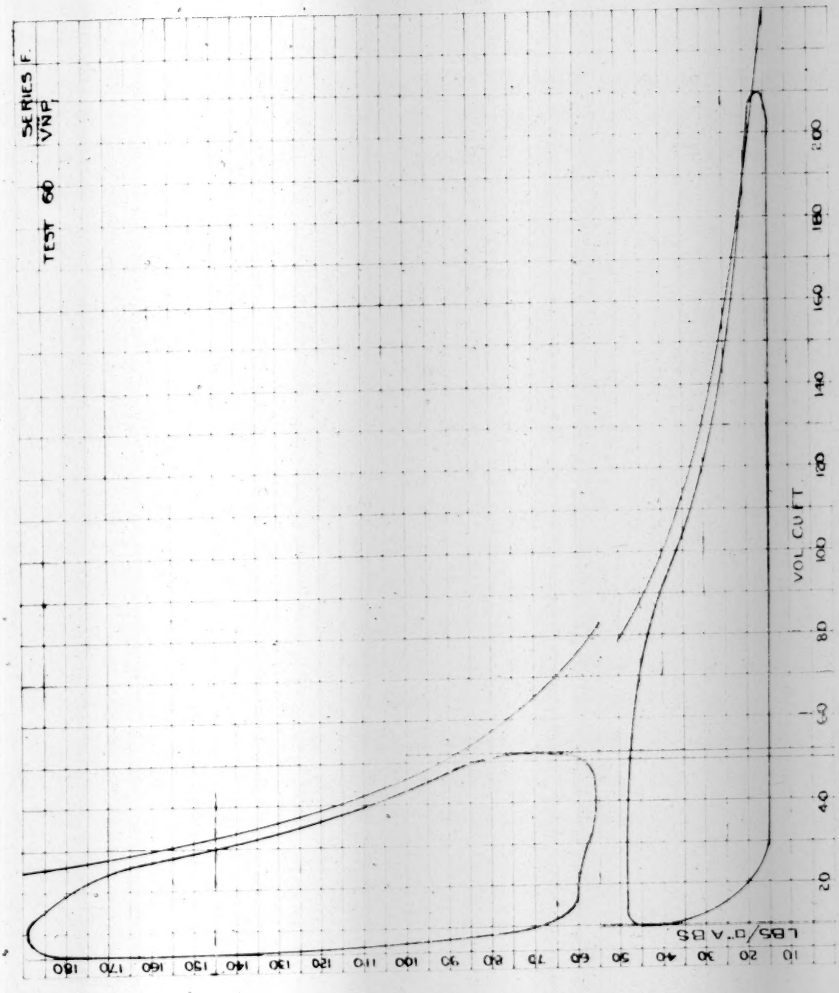


FIG. 29 SERIES F, TEST 60

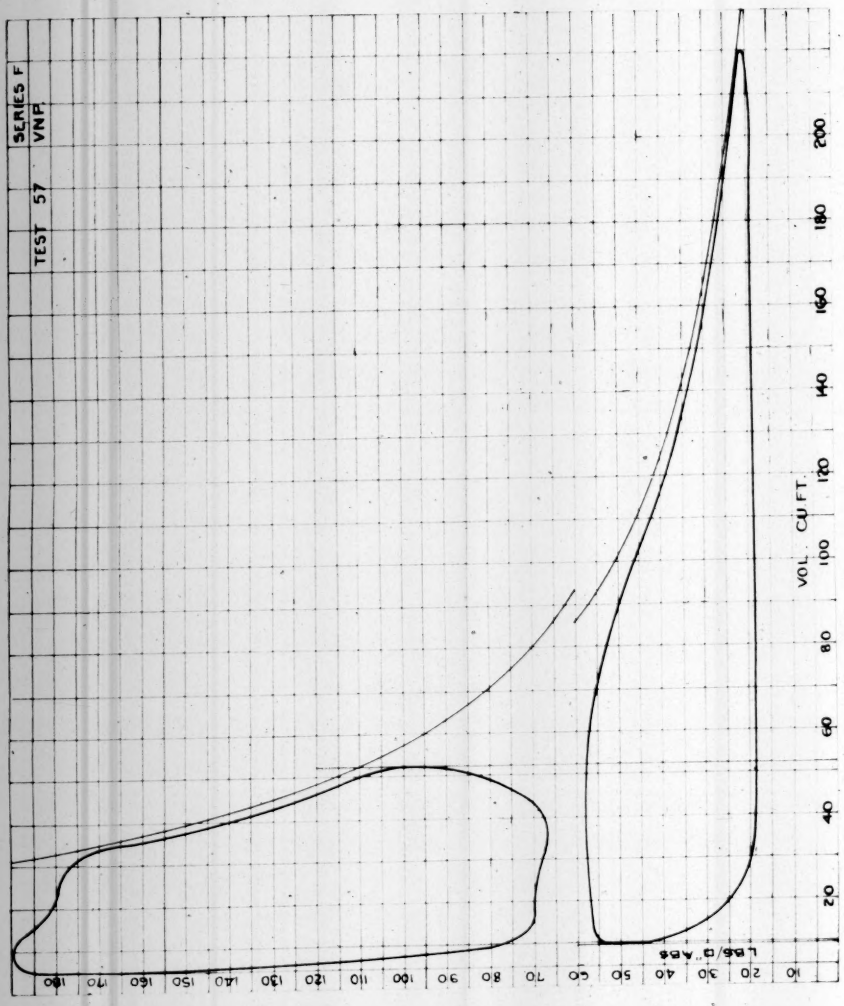


FIG. 30 SERIES F, TEST 57

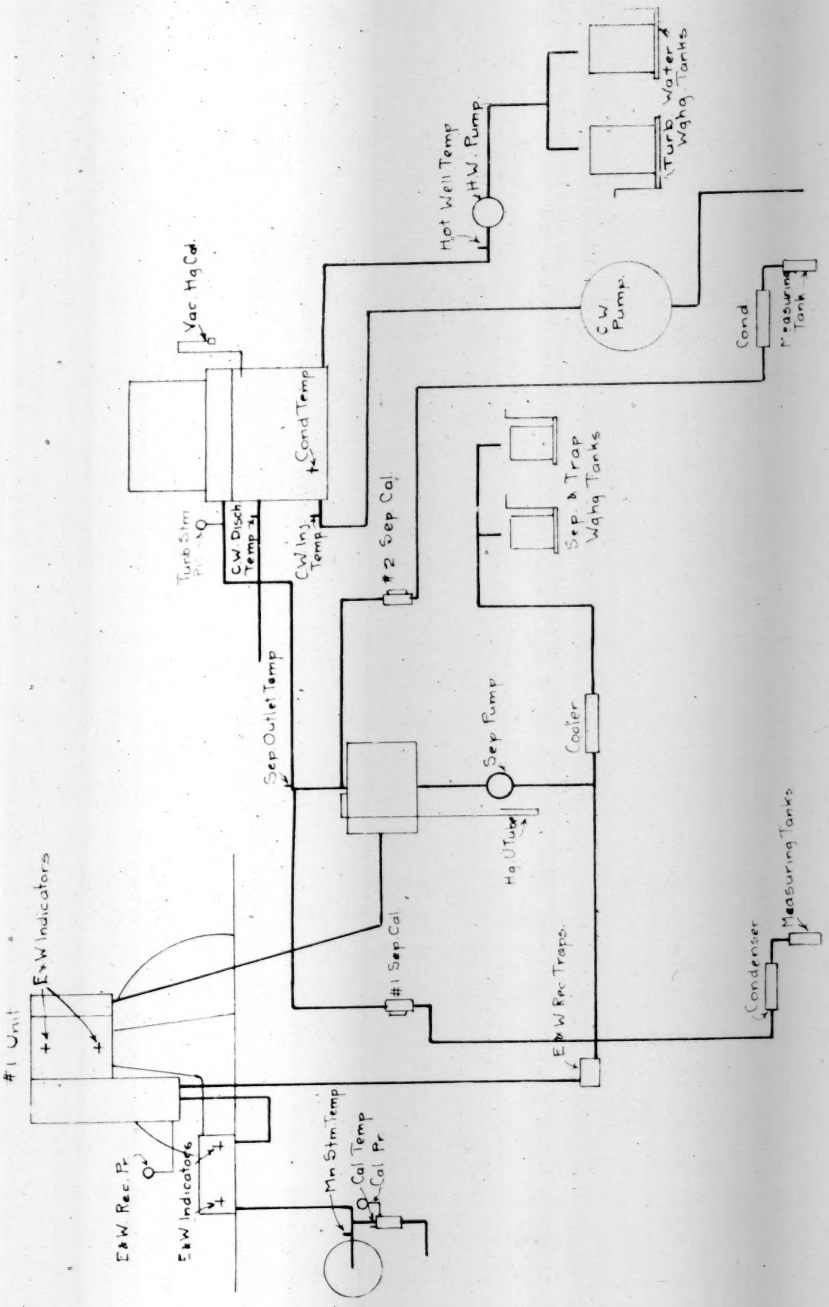


FIG. 31 SERIES C, DIAGRAMMATIC TEST LAYOUT

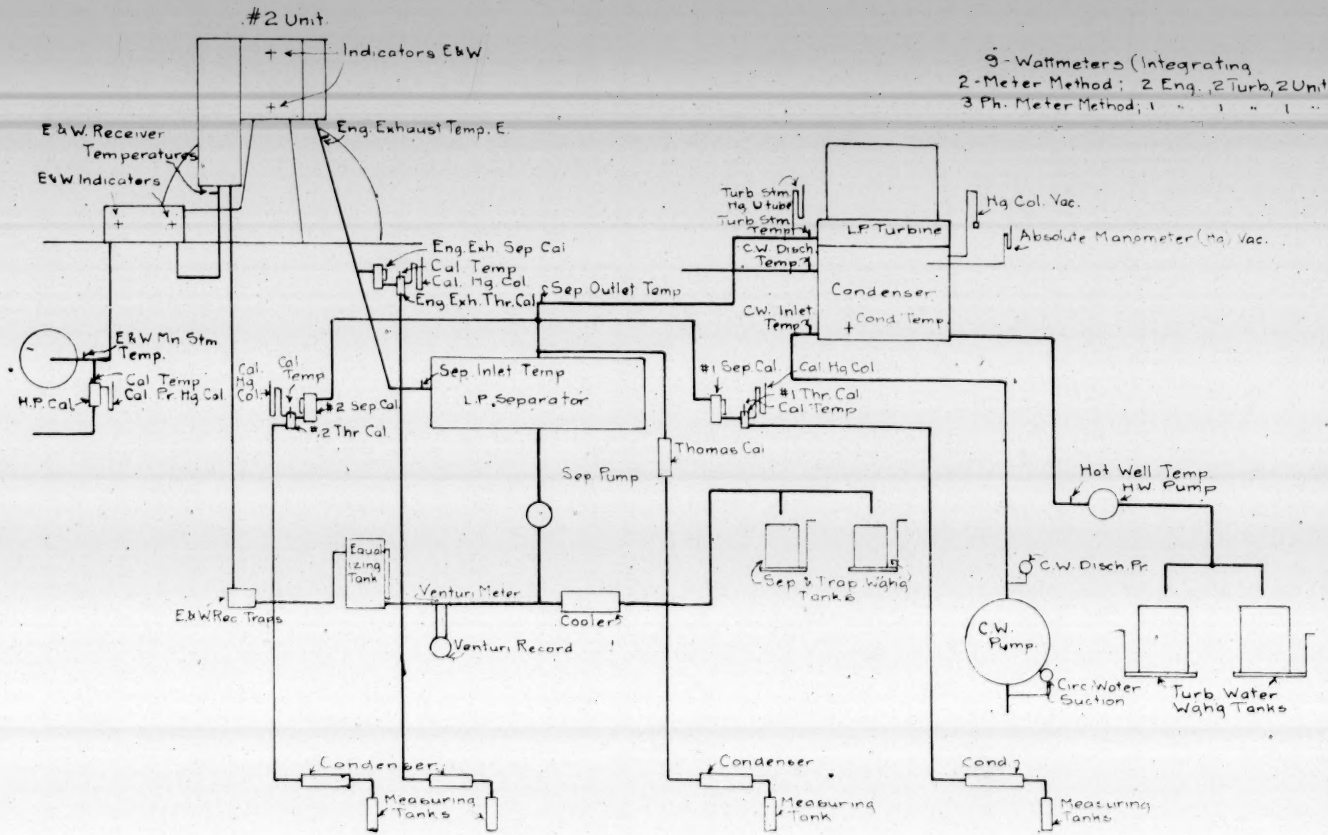


FIG. 32 SERIES D, E AND F, DIAGRAMMATIC TEST LAYOUT

ENGINE

2-H.P CYL 42"x60", 9" rod
2-L.P. " 86"x60", 10" rod
R.P.M. 75
2-14" STM MAINS
2-16" H.P EXH.
2-30" L.P. "
Clearances
H.P Head 9.5% Crank 10.0%
L.P " 4.77 " 4.78
Avge Total Volume H.P 51.7 cu ft
L.P 209.9 " "

Avge. Displacement H.P 47.0 " "
L.P 200.3 " "

I.H.P Constant H.P 15.38 L.P 65.57 (Avge)

All Combined Cards Worked out on Avge Basis
Marks & Davis Tables Used for Steam Data

TABLE II

E_r = Rankine Thermal Eff., cyclic
E_t = Engine " "
H_1 = Heat in initial steam @ press. p_1, quality x (Total per Hr)
H_2 = " " stm. @ p_2, x_2, after adiab. exp from p_1, x_1 (Tot p/Hr)

$\frac{H_1 - H_2}{H_1} = E_r$ $\quad E_t = \frac{KW \times 3412}{H_1}$ $\quad \frac{E_t}{E_r} = E_e$ = Eng Eff. Refd to Rankine Cycle

No Heat Recovered.

TABLE III

p_a, V_a = press. & vol. @ H.P cutoff, lbs □" & cu ft
p_c, V_c = " " " @ H.P Compression
ω_a = spec. density @ p_a
ω_c = " " " p_c

$V_a\omega_a - V_c\omega_c = W$, lbs indicated stm/stroke

$\frac{W \times 75 \times 4 \times 60}{I.H.P}$ = Indicated Water Rate I.W.R.

$I.W.R(1+y) = A.W.R.$ actual Water Rate

$y = .129(r - 6)$ $\quad$ K.W. x 1.465 = I.H.P.

$r = \frac{51.7}{V_a}$ for H.P cyl. = Ratio of Expansion

TABLE IV

Q_e = Total Dry Stm. p Hr. to Eng.
Q_f = Trap Water/Hr
x_e = L.P Exhaust quality

$(Q_e - Q_f)x_e$ = Dry Stm to Turb, Q_t

TABLE VI & VII

x_t = Quality of Stm. to Turb after passing Separator
$1 - x_t = w$, wetness do.
K_e = Eng. K.W. Output
K_t = Turb. " "

FIG. 33 FORMULAE AND CONSTANTS

TABLE VI & VII (Cont.)

Q_e = Dry Steam to Unit/Hr.

$\frac{Q_e}{K_e + K_t}$ = Actual Water Rate, W for Unit

Q_t = Trap Water/Hr.
Q_s = Separator Water/Hr
x_1 = HP Quality
$\frac{Q_e - Q_s - Q}{x_1} = Q_t'$
$Q_t' x_t = Q_t$

$\frac{Q_t}{K_t}$ = Actual Turb. Water Rate, W_t

$\frac{Q_e}{K_e}$ = " Eng " , W_e

$\frac{Q_e}{K_e + K_t(1+w)}$ = Unit W.R., corrected for Moisture In Turb. Stm., W'
$W' - (28.5 - p_3') = W''$ Total Corrected Unit W.R.
p_3' = Actual Vacuum Obtained, " Hg

TABLES IX & X

All Throttling Calorimeters
$x_1 = \frac{H_2 + K(T - t_2) - q}{L}$

H_2 = Tot. Heat/Lb sat. stm @ p_2, cal. disch. pr.

All Separating Cals.
$x_2 = \frac{W_t}{W_m + W_t}$
W_m = Moisture
W_t = Flow

x_1 = quality
K = Sp. Ht. Superheated stm. @ p_2, T
T = temp. Sup. stm. in Cal.
t_2 = " Sat. " @ p_2
q = Heat/Lb. of the liquid
L = Latent Ht. vaporization/Lb @ p_1

All Combination Sep.—Throt. Cals.
$x_1 x_2 = x$, Combined Quality

Thomas Electric Cal.
$\frac{\frac{3.412E}{W} - K(T-t)}{L} = 1 - x$

E = Watt Hrs. Input
W = Lbs. Stm Flow
K = as above
T = " "
t = Sat. stm temp @ p
L = Latent Ht/lb @ p
x = as above

TABLE XII, see VI, VII

TABLES XIII, XIV

$E_t = \frac{K.W. 3412}{H_1}$ for Eng. Turb. or Unit

$E_t' = \frac{K.W. 3412}{H_1 - q}$ for Unit & Turbine Only

E_t = Therm Eff. No Heat Recovered
E_t' = " " Hot Well Heat "

FIG. 33a FORMULAE AND CONSTANTS

FOLDER No. 1

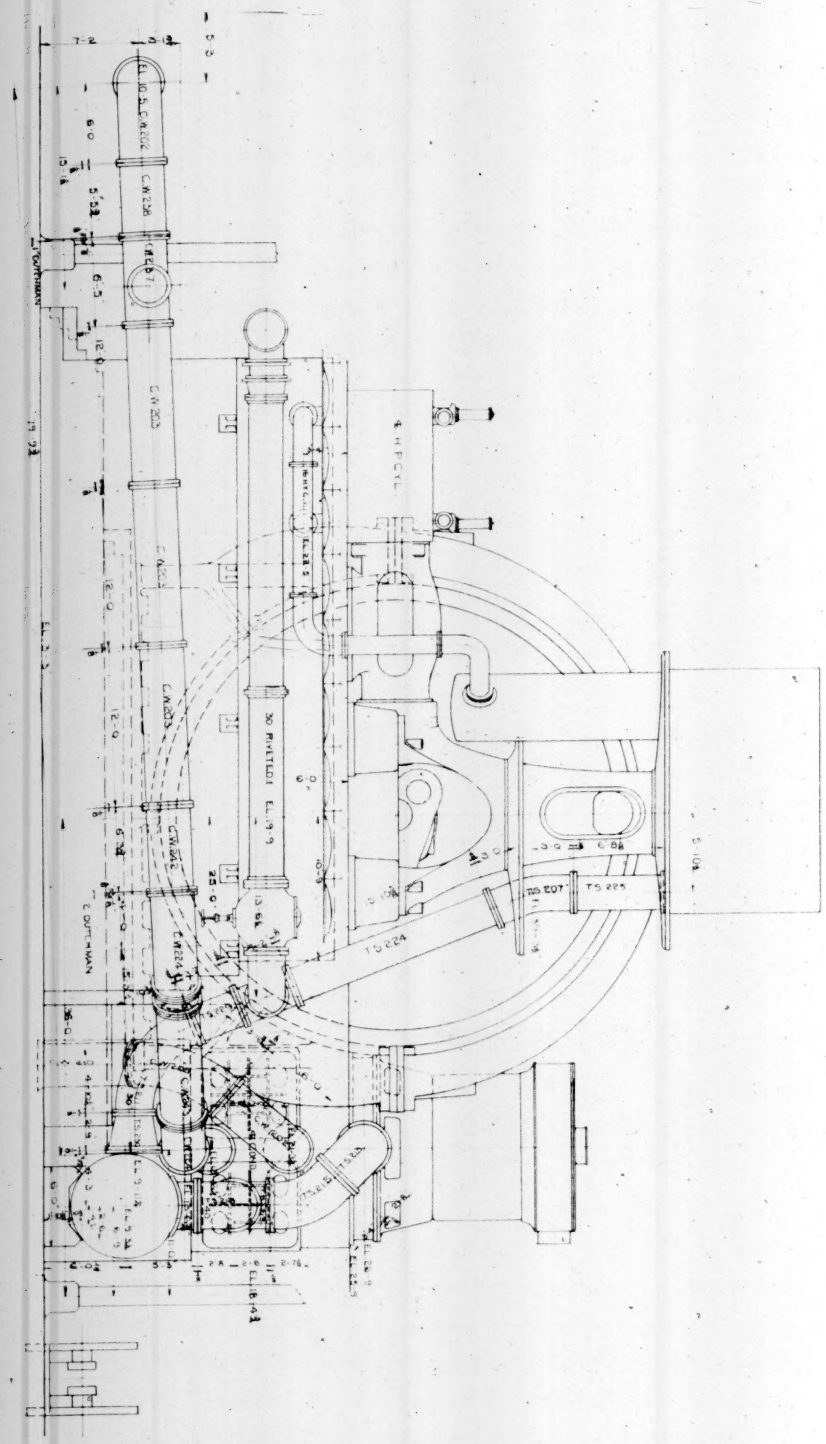
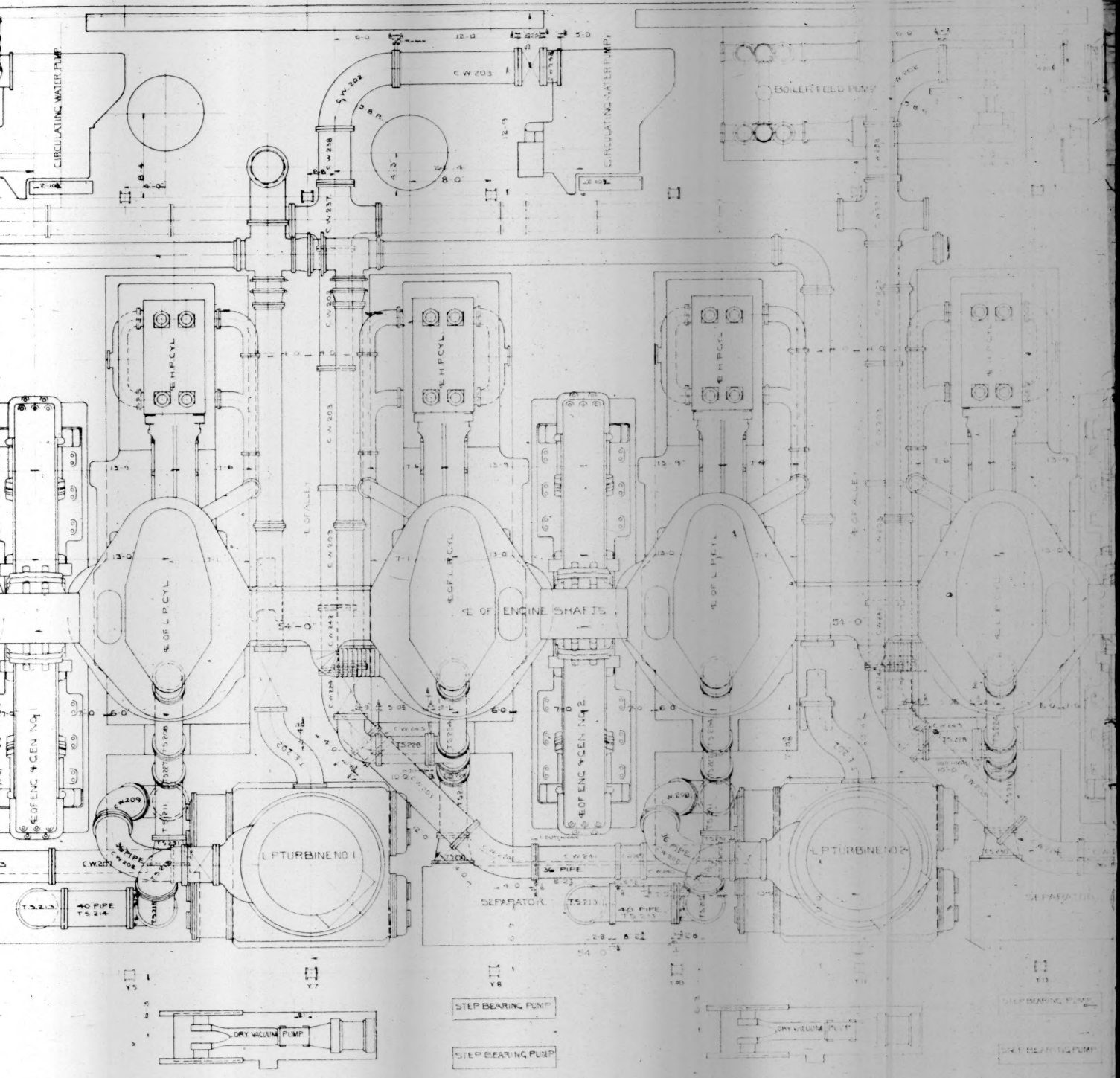


PLATE 1 END ELEVATION AND PLAN OF E



OF ENGINE AND LOW-PRESSURE TURBINE UNITS; 59TH STREET STATION, INTERBOROUGH RAPID TRANSIT COMPANY

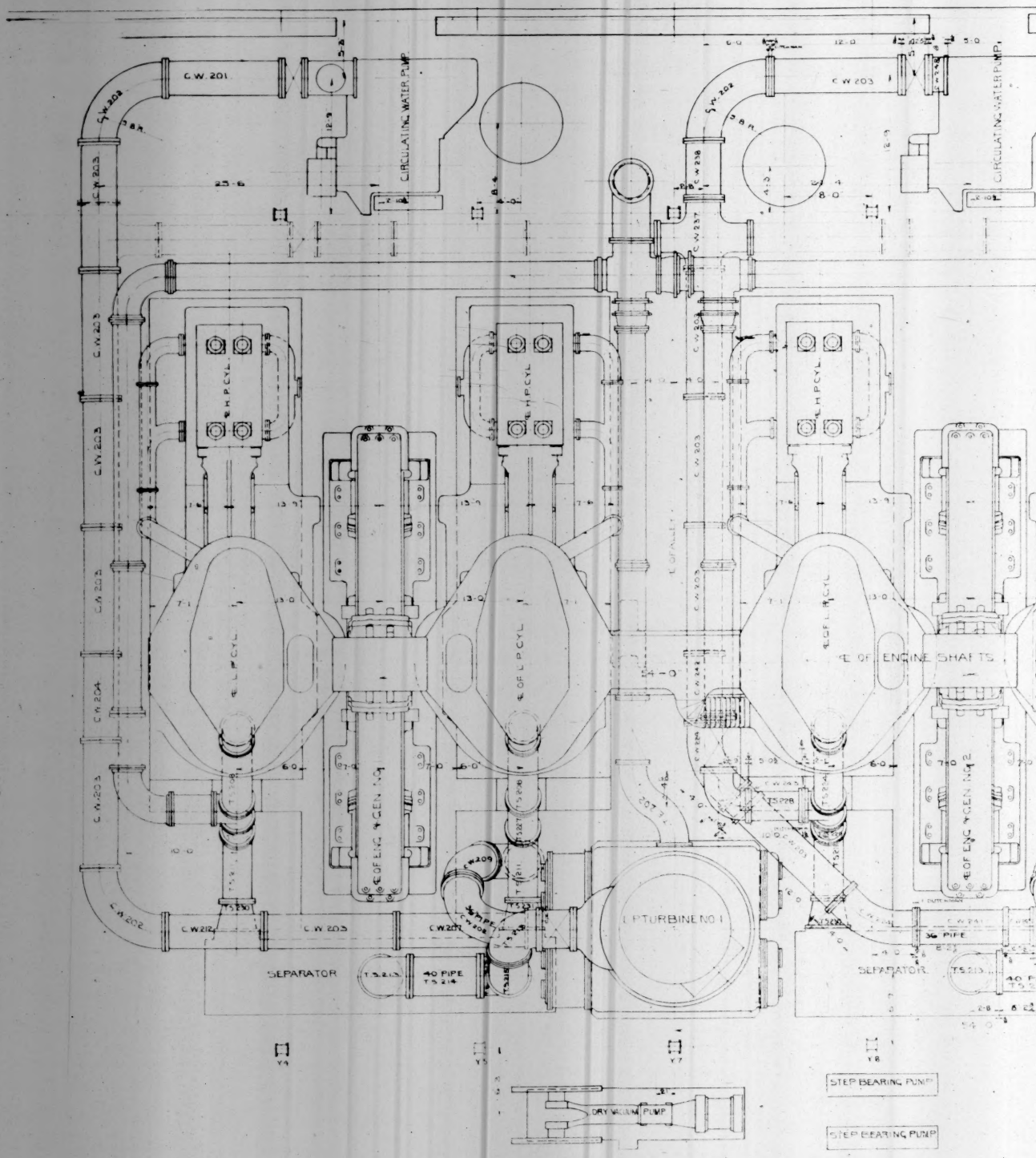
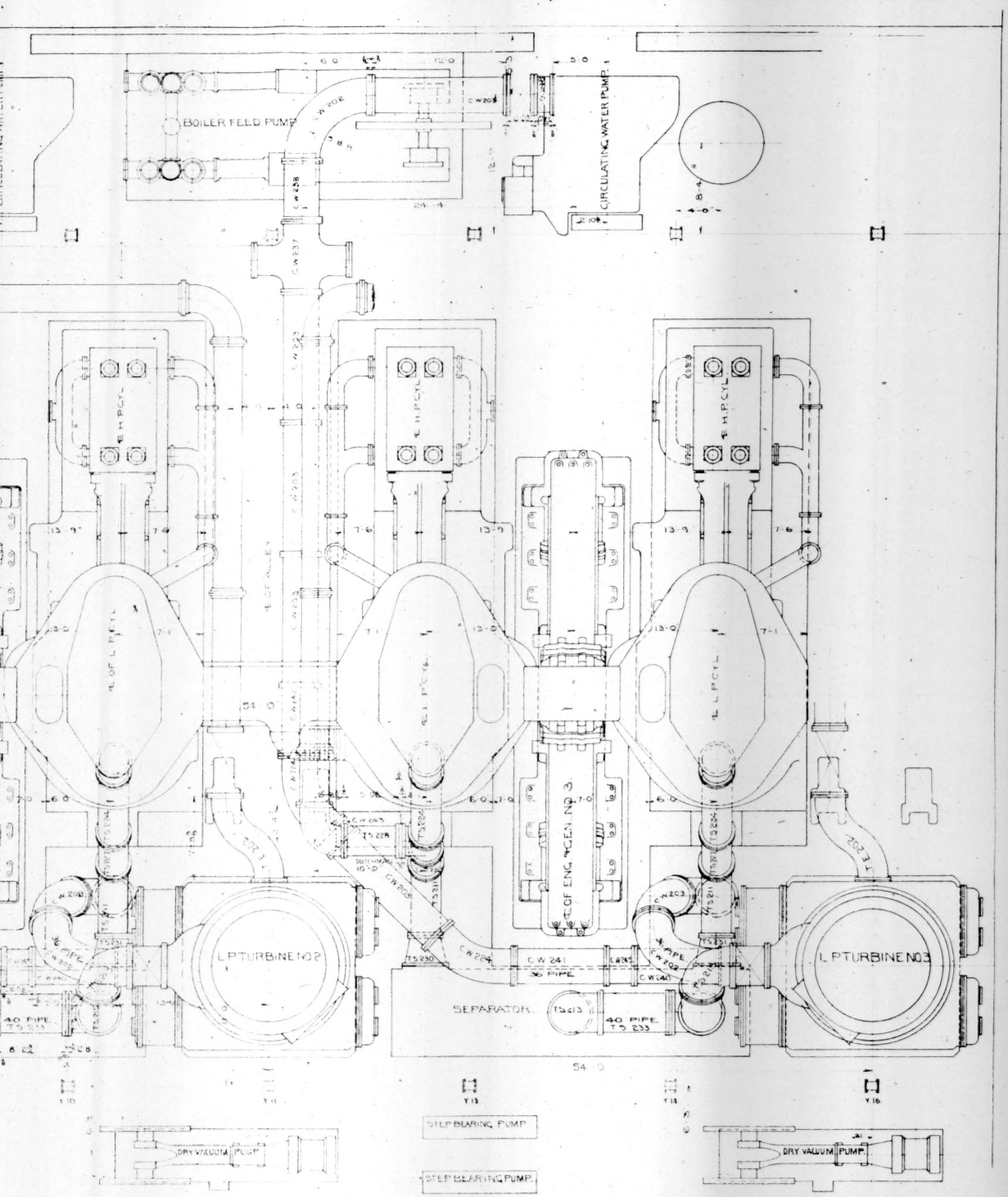
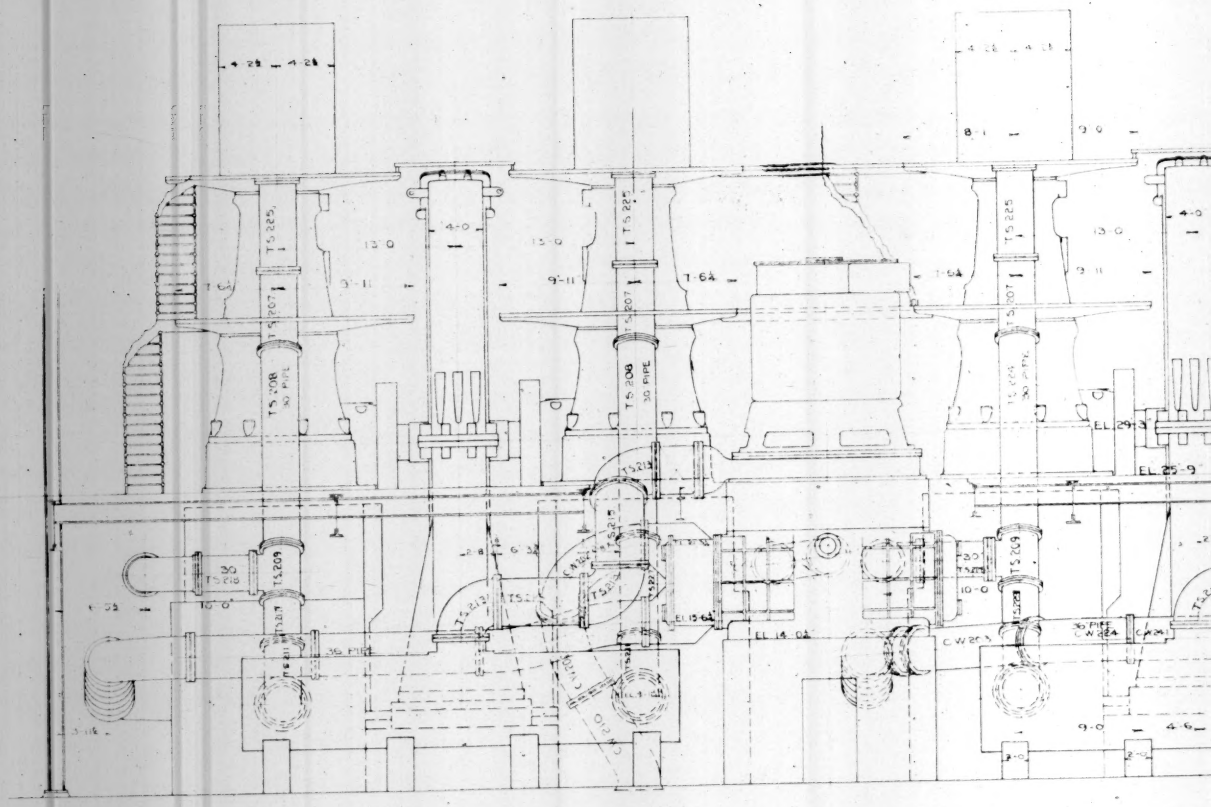


PLATE 1 END ELEVATION AND PLAN OF ENGINE AND LOW-PRESSURE TURBINE UNITS; 59TH STREET STATION, INTERBORO



BOROUGH RAPID TRANSIT COMPANY

FOLDER No. 2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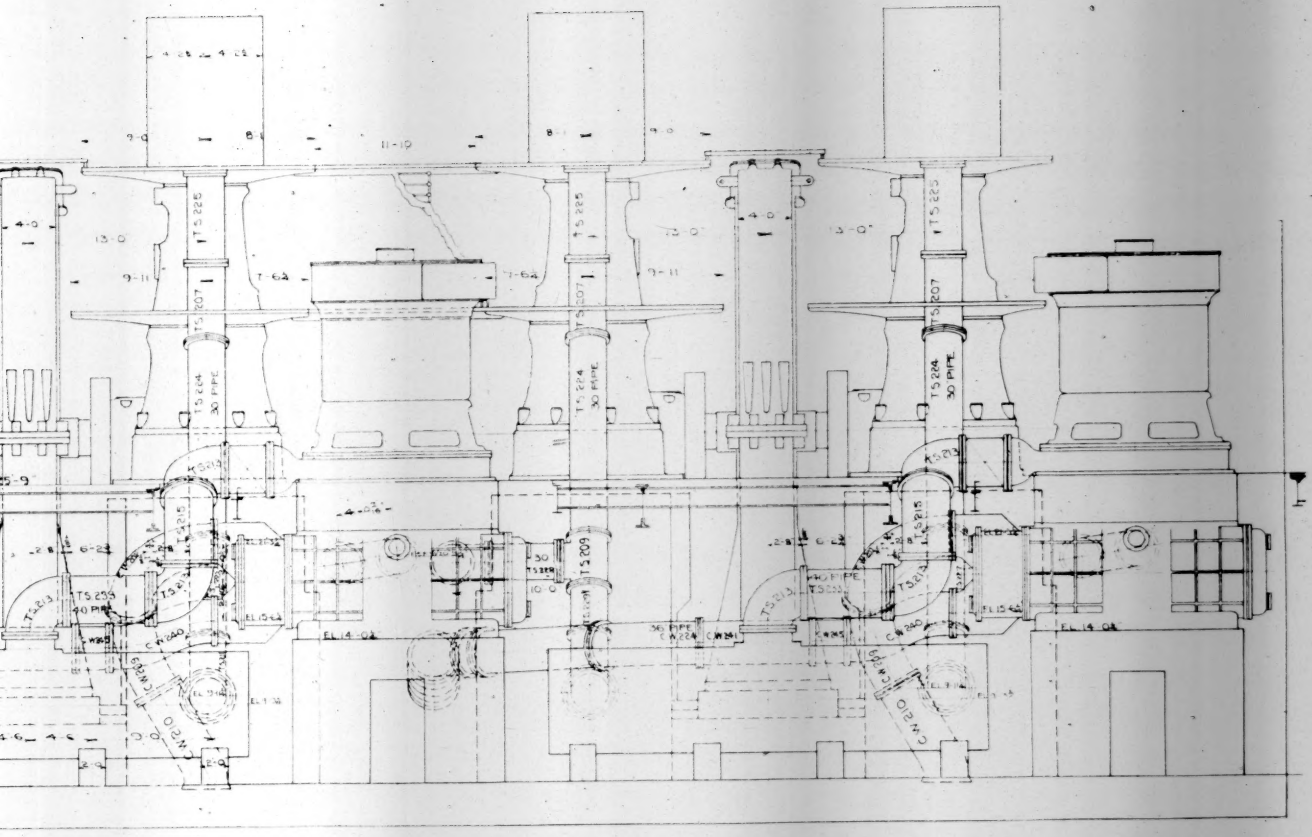

INE UNITS; 59TH STREET STATION, INTERBOROUGH RAPID TRANSIT COMPANY

THE ELASTIC LIMIT OF MANGANESE AND OTHER BRONZES

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To keep up with the demands upon the laboratory for more work in a given time, testing machines have been speeded up and the slow extensometer has largely been displaced by the dividers, used either unchanged or with some means of magnification. To represent castings and forgings the short test piece with one-half inch diameter and two-inch gage length is almost universal. As a consequence, while reports of tests usually include a statement of "elastic limit," the property of the material actually determined is in reality that more or less vague value called the yield point. It is the object of this paper to show that while the yield point for steel is so well marked in properly conducted tests, and bears a sufficiently definite relation to the true elastic limit to warrant the dependence placed upon it by the engineer, there is no equally well defined point found in testing bronzes, and the value commonly obtained from rapid commercial tests as the elastic limit or yield point on bronze may be quite misleading.

2 Manganese bronze was selected as the metal to be subjected to the series of tests here recorded because, of the modern alloys, it is one of the strongest and is readily obtainable in the market. It is not proposed, however, to discuss at length the properties of manganese bronze as such. This metal is used as a type and the results, so far as behavior under a tensile test is concerned, may be taken as typical of brasses and bronzes in general, at least so far as they have come under the observation of the author in some seventeen years of testing materials.

3 Specifications issued by the Navy Department for managanese

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bronze, March 30, 1909, required the following approximate composition:

Copper	52 per cent
Iron	1 per cent
Zinc	46 per cent
Tin	1 per cent
Manganese	Trace
Aluminum	0.5 per cent

The specification further required:

Tensile Strength	65,000 lb. per sq. in.
Elastic Limit	30,000 lb. per sq. in.
Elongation	15 per cent in 2 in.
Reduction of area	25 per cent

They state "the elastic limit is to be the yield point, measured by the drop of the bar."

4 Manganese bronze castings in the form of cylindrical bars about $1\frac{1}{2}$ in. in diameter by 24 in. long, were ordered from several foundries supplying this alloy; the orders were placed through the regular channels, bars of about this size being required in ordinary production. In this way it was hoped that commercial material would be obtained, such as might be expected in castings of more intricate shape. The results on these specimens, ordered without reference to intended use, checked very well with those upon samples submitted previously by the same parties, especially for the purpose of showing the qualities of their material. To indicate the effect of working upon the metal, there were also ordered two bars of the same dimensions hot-rolled to size, and two bars hot-rolled and cold-drawn. The effect of the cold drawing was lost to a great extent by the necessary turning off of the surface in preparing the specimen for test. Much of the cold-drawn metal is used in this way, however, when screw threads are required to provide means of fastening the part in place in the structure. From the bars so obtained, specimens were turned which provided a test section 1 in. in diameter by 8 in. between gage marks, and which had, for the purpose of gripping, ends $1\frac{1}{2}$ in. in diameter threaded to fit the nuts required by the testing machine.

5 Some of these specimens were pulled in the laboratory of the General Electric Company at Schenectady, some in the testing machine at the United States Arsenal at Watertown, and others in the laboratory of the Halcomb Steel Company at Syracuse. The tests

in the Halcomb laboratory were made to obtain autographic strain diagrams; the other tests were made with an extensometer.

6 In the tests with the extensometer, after the instrument had been placed, an initial load of 1000 or 2000 lb. per sq. in. was applied and the first reading taken; readings were than obtained at successive

TABLE 1 CAST MANGANESE BRONZE, MARK 9902 B

EXTENSOMETER TEST

Original Diameter, 0.9995 in. Original length, 8 in.

STRESS		EXTENSOMETER READINGS		MEAN DIFFERENCE	STRAIN	
					Total	Unit
Actual	Per Sq. In.	Right	Left	Initial Reading		
1,570	2,000	0.0235	0.0075			
3,140	4,000	0.0245	0.0089	0.00120	0.0012	0.00015
4,710	6,000	0.0254	0.0107	0.00135	0.00255	0.00032
6,275	8,000	0.0263	0.0122	0.00120	0.00375	0.00047
7,845	10,000	0.0272	0.0136	0.00115	0.00490	0.00061
9,415	12,000	0.0282	0.0151	0.00125	0.00615	0.00077
10,985	14,000	0.0293	0.0165	0.00125	0.00740	0.00092
12,555	16,000	0.0306	0.0181	0.00145	0.00885	0.00111
14,120	18,000	0.0320	0.0198	0.00155	0.01040	0.00130
15,690	20,000	0.0342	0.0219	0.00215	0.01255	0.00157
17,260	22,000	0.0370	0.0246	0.00275	0.01530	0.00191
18,830	24,000	0.0414	0.0279	0.00385	0.01915	0.00239
20,400	26,000	0.0456	0.0321	0.00420	0.02335	0.00292
53,040	67,600	Tensile Strength				

Reduced diameter..... 0.695 in.
Reduction of area..... 51.6 per cent
Length after test..... 10.20 in.
Elongation..... 27.5 per cent
Elastic limit (from curve) 15,000 lb. per sq. in.
Modulus of elasticity 12,900,000 lb. per sq. in.

COMMERCIAL TEST

Original diameter..... 0.503 in.
Original length..... 2 in.
Reduced diameter..... 0.387 in.
Length after test..... 2.65 in.
Reduction of area..... 40.8 per cent
Elongation..... 32.5 per cent
Rapid stretch (yield point) 26,000 lb. per sq. in.
Tensile strength..... 69,650 lb. per sq. in.

loads applied in equal steps. In some cases, the readings were continued regularly until the increase in extension per increment of load was so great that there was no doubt that the strain diagram had departed markedly from the straight line demanded by Hook's law; in other tests, the normal succession of readings was continued only

TABLE 2 CAST MANGANESE BRONZE. MARK 9902-A

Extensometer test

Original diameter 0.995".
Original length 8.".

Stress		Extensometer Readings		Strain		
				Mean Difference	Total	Unit
Actual	Per Sq. In.	Right	Left			
					Initial Reading	
1,570	2,000	0.0255	0.0125			
3,140	4,000	0.0270	0.0133	0.00115	0.00115	0.00014
4,710	6,000	0.0282	0.0147	0.00130	0.00245	0.00031
6,275	8,000	0.0290	0.0163	0.00120	0.00365	0.00046
7,848	10,000	0.0298	0.0179	0.00120	0.00485	0.00061
9,415	12,000	0.0307	0.0194	0.00120	0.00605	0.00076
10,985	14,000	0.0318	0.0208	0.00125	0.00730	0.00091
12,555	16,000	0.0328	0.0223	0.00125	0.00855	0.00107
14,120	18,000	0.0342	0.0239	0.00150	0.01005	0.00126
1,570	2,000	0.0264	0.0122	0.0003	set	
14,120	18,000	0.0345	0.0232			
15,690	20,000	0.0360	0.0253	0.00180	0.01185	0.00148
1,570	2,000	0.0270	0.0125	0.00075	set	
15,690	20,000	0.0365	0.0250			
17,260	2,2000	0.0384	0.0273	0.00210	0.01395	0.00174
18,830	24,000	0.0412	0.0301	0.00280	0.01675	0.00209
1,570	2,000	0.0291	0.0140	0.00265	set	
18,830	24,000	0.0418	0.0296			
20,400	26,000	0.0446	0.0332	0.00320	0.01995	0.00249
53,480	68,160	Tensile Strength				

Reduced diameter	0.717 in.
Reduction of area	48.5 per cent
Length after test	10.22 in.
Elongation	27.8 per cent
Elastic limit (from curve)	16,000 lb. per sq. in.
Modulus of elasticity	13,000,000 lb. per sq. in.

Commercial Test

Original diameter	0.5028 in.
Original length	2 in.
Reduced diameter	0.338 in.
Length after test	2.84 in.
Reduction of area	54.8 per cent.
Elongation	42.0 per cent
Rapid stretch (yield point)	25,000 lb. per sq. in.
Tensile strength	67,940 lb. per sq. in.

until the first positive increase in extension per increment of load was noted, when the stress was reduced to the initial load for the measurement of permanent set, after which the load was returned to the value just left, a new reading taken and the test continued with further determinations of set intervals. The values of stress and corresponding strain obtained were plotted, and the elastic limit recorded as the stress at the point of inflexion of the curve drawn through the points.

7 The specimens subjected to these tests were about 12 in. long over all. From the remainder of the 24-in. bars, the usual $\frac{1}{2}$ in. by 2

TABLE 3 EXTENSOMETER AND COMMERCIAL TESTS

EXTENSOMETER TESTS: ALL SPECIMENS 1 IN. (APPROXIMATE) DIA. BY 8 IN. LONG.

Mark	9908B	Q2992A	Q2992B	Q6434A
Sample	Cast	Hot-Rolled	Hot-Rolled	Cold-Drawn
Reduction of area, per cent	14.1	52.2	52.2	53.3
Elongation, per cent	6.25	33.5	33.75	31.0
Elastic limit, lb. per sq. in	19,400	18,000	18,000	17,000
Tensile strength, lb. per sq. in	62,070	71,800	71,640	71,620
Modulus of elasticity, lb. per sq. in	13,810,000	13,000,000	13,810,000	12,800,000

COMMERCIAL TESTS: ALL SPECIMENS 0.5 IN. (APPROXIMATE) DIA. BY 2 IN. LONG.

Sample	Cast	Hot-Rolled	Hot-Rolled	Cold-Drawn
Reduction of area, per cent	28.5	44.9	45.9	39.9
Elongation, per cent	26.5	37.5	36.5	34.0
Yield Point (rapid stretch), lbs. per sq. in	29,000	30,000	30,000	43,000
Tensile strength, lbs. per sq. in	80,420	74,780	74,480	74,260

Bar 9908B was unsound, hence $\frac{1}{2}$ in. by 2 in. test was turned from side of bar, instead of center. Unsoundness due to oxidation and perhaps segregation, probably accounts for the apparent cold shortness of the 1 in. by 8 in. test piece. Fracture occurred in a flaw, while many incipient fractures or cracks were noted in surface before final rupture.

in. test pieces were turned and tested in the customary commercial way, using a pair of multiplying dividers to indicate the point of increase in rate of stretch or yield point.

8 In Table 1 are given in detail a typical set of readings taken in a test at regularly increasing loads, together with the results of the commercial test upon the specimen from the same bar. In Table 2, similar data are given from a test with measurements of set. Table 3 shows the results obtained upon the other specimens tested at Schenectady. The curves for all these tests are assembled on Fig. 1. Details of the tests at the Watertown Arsenal are stated in Tables 4

and 5, and the curves from these data are given on Fig. 2. The results of the work at the Halcomb laboratory are shown in Table 6 and Fig. 3; the scale of the diagram is so small that the location of the point of inflexion is uncertain within about 2000 lb. actual load, and the values in the tables are placed rather high. The multiplying dividers used in the commercial tests here recorded magnify the movement of the gage marks about ten times, and are a much more sensitive instrument than the machinists' dividers for locating the yield point; hence, the yield points recorded are lower than are usually reported.

9 In the text books and elsewhere, the limit of elasticity is defined

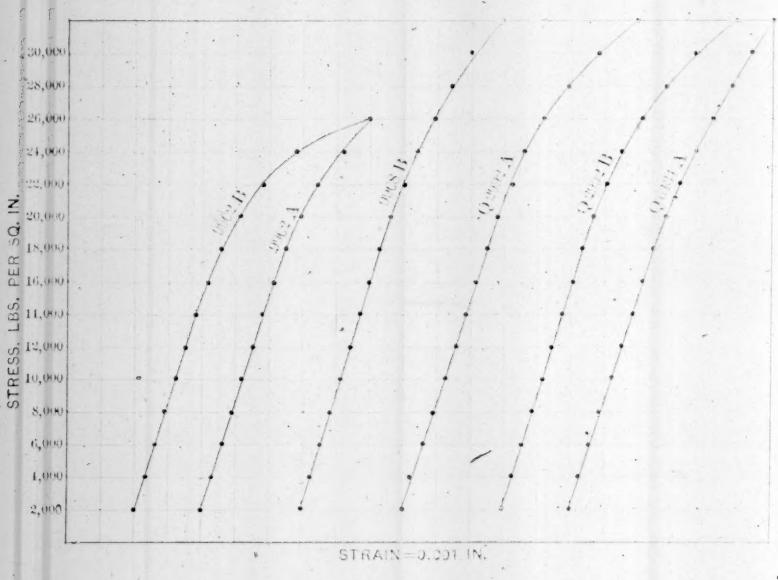

FIG. 1 CURVES PLOTTED FROM DATA IN TABLES 1, 2 AND 3

as that value of stress beyond which there is not full recovery of the initial dimensions or shape of the specimen after release of the load, or as the maximum stress that can be applied without producing permanent set. In other words, it is the value of stress beyond which Hook's law no longer holds, and it is sometimes spoken of as the limit of proportionality of stress to strain.

10 Accepting this definition of elastic limit, it is seen that its value in the bronzes tested is from 16,000 lb. per sq. in. to 23,000 lb. per sq. in., whereas the yield points found for the cast metals ran from 25,000 lb. to 29,000 lb., and for the worked metals, from 30,000

TABLE 4 CAST MANGANESE BRONZE, MARK 9902 B

WATERTOWN ARSENAL TEST

Original Diameter, 1.000 in. Original length, 8 in.

STRESS		STRAIN				
		READING	DIFFERENCE			SET
Actual	Per Sq. In.			Total	Unit	
				Initial Reading		
785	1,000					
1,571	2,000	0.0008	0.0008	0.0008	0.00010	.....
2,356	3,000	0.0013	0.0005	0.0013	0.00016	.....
3,142	4,000	0.0020	0.0007	0.0020	0.00025	.....
3,927	5,000	0.0027	0.0007	0.0027	0.00034	0
4,712	6,000	0.0033	0.0006	0.0033	0.00041	.....
5,498	7,000	0.0038	0.0005	0.0038	0.00048	.....
6,283	8,000	0.0044	0.0006	0.0044	0.00055	.....
7,069	9,000	0.0051	0.0007	0.0051	0.00064	.....
7,854	10,000	0.0060	0.0009	0.0060	0.00075	0
8,639	11,000	0.0067	0.0007	0.0067	0.00084	.....
9,425	12,000	0.0075	0.0008	0.0075	0.00094	.....
10,210	13,000	0.0080	0.0005	0.0080	0.00100	.....
10,996	14,000	0.0086	0.0006	0.0086	0.00108	.....
11,781	15,000	0.0090	0.0004	0.0090	0.00113	0
12,566	16,000	0.0105	0.0015	0.0105	0.00131	.....
13,352	17,000	0.0119	0.0014	0.0119	0.00149	0.0005
14,137	18,000	0.0133	0.0014	0.0133	0.00166	.....
14,923	19,000	0.0145	0.0012	0.0145	0.00181	.....
15,708	20,000	0.0167	0.0022	0.0167	0.00209	0.0025
19,635	25,000	0.0280	0.0113	0.0280	0.00350	0.0085
23,562	30,000	0.0487	0.0207	0.0487	0.00609	0.0241
31,416	40,000	0.2090	0.1603	0.2090	0.02613	0.1730
50,600	64,458	Tensile Strength				

Reduced diameter ..... 0.70 in.
Length after test ..... 10.53 in.
Reduction of area ..... 51.0 per cent.
Elongation ..... 31.6 per cent.
Elastic limit ..... 16000 lb. per sq. in.
Modulus of elasticity, 12,390,000 lb. per sq. in.

COMMERCIAL TEST (MADE AT SCHENECTADY)

Original diameter ..... 0.503 in.
Original Length ..... 2 in.
Reduced diameter ..... 0.387 in.
Length after test ..... 2.65 in.
Reduction of area ..... 40.8 per cent.
Elongation ..... 32.5 per cent.
Rapid stretch (yield point) ..... 26000 lb. per sq. in.
Tensile strength ..... 69650 lb. per sq. in.

TABLE 5 CAST MANGANESE BRONZE, MARK 9908B

WATERTOWN ARSENAL TESTS

Original diameter, 0.7854 in. Original length, 8 in.

Stress		Strain				
		Reading	Difference			Set
Actual	Per Sq. In.			Total	Unit	
				Initial Reading		
785	1000	0				
1571	2000	0.0007	0.0007	0.0007	0.00009	
2356	3000	0.0013	0.0006	0.0013	0.00016	
3142	4000	0.0017	0.0004	0.0017	0.00021	
3927	5000	0.0023	0.0006	0.0023	0.00029	0
4712	6000	0.0028	0.0005	0.0028	0.00035	
5498	7000	0.0036	0.0008	0.0036	0.00045	
6283	8000	0.0040	0.0004	0.0040	0.00050	
7069	9000	0.0047	0.0007	0.0047	0.00059	
7854	10000	0.0052	0.0005	0.0052	0.00065	0
8639	11000	0.0059	0.0007	0.0059	0.00074	
9425	12000	0.0064	0.0005	0.0064	0.00080	
10210	13000	0.0070	0.0006	0.0070	0.00088	
10996	14000	0.0074	0.0004	0.0074	0.00093	
11781	15000	0.0081	0.0007	0.0081	0.00101	0
12566	16000	0.0088	0.0007	0.0088	0.00110	
13352	17000	0.0094	0.0006	0.0094	0.00118	
14137	18000	0.0099	0.0005	0.0099	0.00124	
14923	19000	0.0104	0.0005	0.0104	0.00130	
15708	20000	0.0113	0.0009	0.0113	0.00141	0.0001
16493	21000	0.0120	0.0007	0.0120	0.00150	
17279	22000	0.0126	0.0006	0.0126	0.00158	
18064	23000	0.0135	0.0009	0.0135	0.00169	0.0003
18850	24000	0.0143	0.0008	0.0143	0.00179	
19635	25000	0.0156	0.0013	0.0156	0.00195	0.0010
20420	26000	0.0165	0.0009	0.0165	0.00206	
21206	27000	0.0171	0.0006	0.0171	0.00214	0.0015
21991	28000	0.0185	0.0014	0.0185	0.00231	
22777	29000	0.0200	0.0015	0.0200	0.00250	
23562	30000	0.0210	0.0010	0.0210	0.00263	0.0034
27489	35000	0.0325	0.0115	0.0325	0.00406	0.0118
31416	40000	0.0607	0.0282	0.0607	0.00759	0.0384
35343	45000	0.1225	0.0618	0.1225	0.01531	0.0920
53900	68662	Tensile Strength				

Reduced diameter	0.91 in.	Elongation	10.6 per cent.
Length after test	8.85 in.	Elastic limit	23000 lb. per sq. in.
Reduction of area	17.2 per cent.	Modulus of elasticity,	13,300,000 lb. per sq. in.

COMMERCIAL TEST (MADE AT SCHENECTADY)

Original diameter	0.504 in.	Length after test	2.53 in.
Original length	2 in.	Elongation	26.5 per cent.
Reduced diameter	0.426 in.	Rapid stretch (yield point)	29,000 lb. per sq. in.
		Tensile strength	80,420 lb. per sq. in.

lb. to 44,000 lb. per sq. in. Had ordinary dividers been used, the values for the cast metals would have been placed between 30,000 lb. and 40,000 lb. per sq. in. The strain diagrams from the extensometer tests show the general shape of the elastic curve of the metal, and permit the accurate fixing of the point of inflexion of the curve; the autographic diagrams, however, show not only the actual shape of the curve, but also why there is the uncertainity in the locating of the yield point or point of rapid increase in rate of stretching.

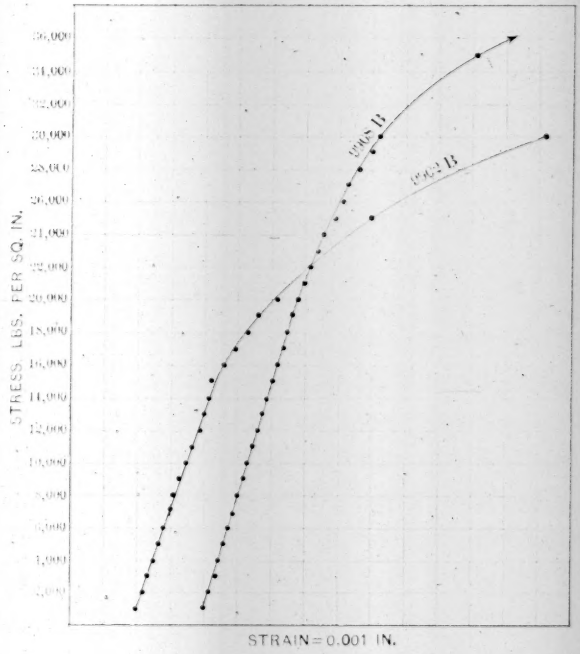

FIG. 2 CURVES PLOTTED FROM DATA IN TABLES 4 AND 5

11 For comparison, the autographic diagram of a piece of commercial "structural medium" steel is shown as No. 1 in Fig. 3. At the scale of the diagram, no inflexion of the curve is seen until it suddenly breaks sharply, actually drops and remains practically horizontal until it finally picks up again. This jog is entirely characteristic of mild steel, and is found to a more or less marked extent in all steels, save perhaps the very hard varieties. There is, however, no break of any sort in the curves obtained from bronze; they are entirely smooth. Somewhere along the knee of the curve, the tester

notes that the material is stretching faster; just where he notices it will depend upon the sensitiveness of the means employed to indicate stretch, and upon his skill and sharpness in observation. The jog in the steel curve is indicated simultaneously by the slipping of the dividers and by the dropping of the scale beam of the testing machine driven at constant speed. The scale beam does not drop when testing bronze; the operator finds the poise gradually traveling more

TABLE 6 HALCOMB STEEL COMPANY TESTS

AUTOGRAPHIC TESTS ALL SPECIMENS 1-IN. (APPROXIMATE) DIA. BY 8-IN. LONG.

Mark		9902A	9908A	Q2992A	Q6434A
Number on Curve Sheet	1	2	3	4	5
Sample	Steel	Cast	Cast	Hot-Rolled	Cold-Drawn
Reduction of area, per cent	53.6	8.3	14.1	53.2	38.6
Elongation, per cent	36.3	27.2	6.6	34.4	25.2
Elastic limit, lbs. per sq. in.	38,000	21,400	22,900	22,800	25,200
Tensile strength, lbs. per sq. in.	60,140	69,700	63,940	71,820	68,500

COMMERCIAL TESTS (MADE AT SCHENECTADY): ALL SPECIMENS 0.5 IN. DIA. BY 2 IN. LONG.

Sample	Cast	Cast	Hot-Rolled	Cold-Drawn
Reduction of area, per cent	54.8	22.4	44.9	39.9
Elongation, per cent	42.0	14.5	37.5	34.0
Yield point, lbs. per sq. in.	25,000	26,000	30,000	44,000
Tensile strength, lbs. per sq. in.	67,940	70,900	74,780	74,260

slowly to maintain balance, but who can say when the change in rate began?

12 It is customary to find the yield point in mild steels, and in fact, in annealed steels generally, at about 50 per cent of the maximum strength. The yield point in mild steels corresponds, for all practical purposes, with the elastic limit. As the steel becomes harder, due to increase in carbon or the addition of alloying metals, or to heat treatment, the yield point rises rather more rapidly than the elastic limit, although the difference between the two is not so great but that the former may be used in calculations, and the yield point itself is less sharply marked, though still observable if sufficient care is taken. The yield point in steel is accepted as a safe guide to the engineer, in deciding upon the maximum stresses that may safely be permitted in parts designed to carry load.

13 That no such dependence can be placed upon the so-called yield point, as it is determined upon bronzes, is evident; rather, recourse must be had to the slower but more accurate determination of the true elastic limit if safe data are desired. It is especially noteworthy that the sets found at the minimum values of yield point as usually reported are a very considerable proportion of the total stretch that has taken place in the metal at those stresses, and that sets are found at stresses which are but 40 to 50 per cent of these reported yield points. Under certain conditions of dead load, a stress of 75 per cent of the elastic limit is sometimes considered at least not unsafe; if such a load were calculated for bronze, upon the basis of the usual commercial test for yield point, instability of the part so designed would be inevitable.

FIG. 3 AUTOGRAPHIC STRAIN DIAGRAMS TO ACCOMPANY DATA IN TABLE 6.

14 Hot working of the metal has not materially improved its elastic properties, but has greatly increased its toughness, and probably in an extended series of tests, would have been found to impart uniformity. It is well known that this particular alloy is relatively difficult to handle in the foundry because of its sensitiveness to temperature of pouring and to changes in composition, at least in the sense of impurities in the constituent metals, and because of its great shrinkage, requiring large feeders and sink heads. As in other copper alloys, many of the ill effects of this sensitiveness may be largely overcome by hot working. The data here presented are too meager to warrant lengthy discussion of the effects of cold working of the metal; it is shown that in the case of bars of $1\frac{1}{2}$ in. diameter, the effects of the cold drawing may have largely disappeared when $\frac{1}{4}$ in of metal is removed, except as shown in a lessened elongation. Neither hot or cold working cause any change in the elastic curve of the metal; it remains a characteristically smooth curve. In other cold-drawn copper alloys, when tested without removal of surface, the elastic curve

usually presents a much sharper bend at the knee than is found in the cast metal, or in the same metal when annealed; the same would probably be found with manganese bronze if tested as drawn, without turning. Cold-drawn metal, except wire, is seldom used without removal of the surface to provide means of fastening, and it surely is safer to test it as it is used rather than in the perhaps fictitious condition of strength due to skin hardness.

15 These results do not constitute a new discovery. In the literature of testing engineering, references may be found with direct bearing on the subject; but in these days of rapid progress and short-cut methods, much that is old, or that may be found only by search, is apt to be forgotten or overlooked. Comparatively few laboratories have autographic machines, and the use of the extensometer with a specimen only 2 in. long is not very satisfactory because of the small extension of so short a length of material under stress. Many otherwise well equipped laboratories have no extensometer. So much of experience in testing materials is based upon work done upon iron and steel that it was perhaps a natural assumption that the characteristics of these metals would also be found in bronzes and similar alloys and hence that methods of testing used successfully with one would yield equally safe results when applied to the other. Test results which are misleading are exceedingly dangerous; they induce a false sense of security which may result in the failure of structures and lead to the condemnation of a material which would be perfectly satisfactory if properly applied and not unwittingly abused.

16 The author wishes to acknowledge the courtesy of Dr. John A. Mathews, operating manager, and Marcus T. Lothrop, metallurgical engineer, of the Halcomb Steel Company, in furnishing the means of obtaining the excellent autographic strain diagrams reproduced in Fig. 3.

AN IMPROVED ABSORPTION DYNAMOMETER

By C. M. Garland, Urbana, Ill.

Member of the Society

In testing prime movers, the engineer often laments the dearth of efficient power-absorbing apparatus. Especially is this true in the testing of small high-speed machines, such as automobile engines and steam turbines. In many cases the number of machines to be tested is large, in fact in some instances each machine is given a b.h.p. test before leaving the factory; and in every case where a high degree of reliability is essential from the output, the percentage of machines undergoing test must be large. The attention of the writer was forcibly called to this need several years ago in the testing of a small steam turbine running at 2500 r. p. m., and through this experience the type of apparatus described below was designed and has been used with satisfactory results.

2 In the design of such a piece of apparatus, the following points were to be considered. These are enumerated in the order of their supposed importance.

a It should be free from binding or "seizing."

b It should be free from producing changes in the load, due to changes in the apparatus itself, such as change of temperature, wear or friction of parts, etc.

c It should be capable of absorbing and accurately indicating a wide range of loads, from zero to the full capacity of the machine.

d The regulation of the load should be positive and instantaneous.

e The apparatus should require a minimum amount of attention and be capable of continuous service.

f It should be self-contained, occupy a small amount of floor space, and be free from noise and the splashing of oil and water.

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g It should be capable of being quickly changed from one prime mover to another.

h It should require a small amount of cooling water.

3 In considering the above items, it will be noted that Items *a* and *b* practically eliminate mechanical-friction apparatus from the field, while Items *b*, *c* and *d* practically eliminate machines depending upon the friction or resistance of liquids for their operation. With these two classes of apparatus removed, there only remained the principle of magnetic induction for the construction of an efficient absorption dynamometer.

THEORY

4 From this principle we know that a conductor revolving in a field of variable magnetic intensity has an electric current induced

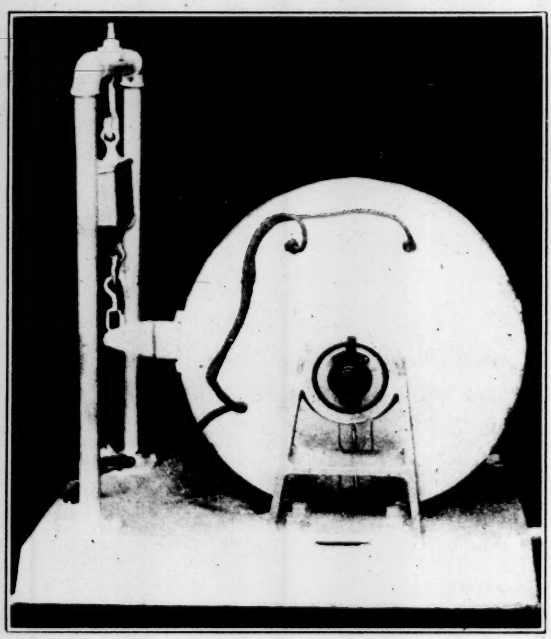


FIG. 1 MAGNETIC ABSORPTION DYNAMOMETER

in it. The reaction of this current upon the field that produces it causes a torque between the conductor and the field. There are two ways of dealing with the current induced in the conductor. In the

one, the current may be collected by a commutator or slip rings and carried off from the machine; in the other, the current, or rather currents, generated in the conductor may be allowed to remain, and, circulating in the paths of least resistance, they will ultimately short-circuit among themselves and produce heat.

5 In the first case, we have simply a dynamo mounted in a cradle. This serves as a very efficient and satisfactory type of dynamometer. There are, however, objections to its use. The currents generated must be taken care of either by water rheostats or lamp banks or utilized in the performance of work. Water rheostats and lamp banks require considerable attention and occupy space. Owing to the irregu-

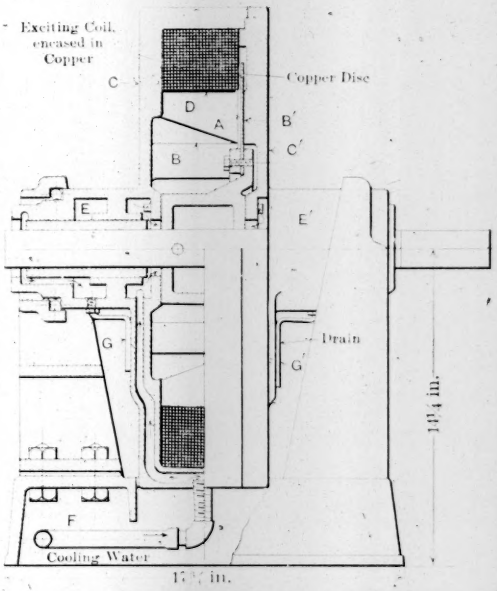


FIG. 2 END ELEVATION AND PART SECTION

larities in the testing, the utilization of the current for the performance of work is in most cases impracticable. The initial cost of a testing unit of this type is necessarily large.

6 If the currents in the conductor are permitted to short-circuit themselves, the conductor is heated; the amount of heat produced is equivalent to the work absorbed by the dynamometer; and the heat thus generated may then be carried off by cooling water. This is the principle utilized in the design illustrated, a description of which follows.

DESCRIPTION

7 In brief, the dynamometer consists of a metallic disc revolving between a set of pole pieces so constructed as to produce a magnetic field of variable intensity. Fig. 1 shows the front view of a machine designed to absorb 45 h. p. at from 1200 to 1500 r.p.m. Fig. 2 is an end elevation and part section showing the construction of the dynamometer. It will be seen from this figure that it consists of a copper disc A, mounted on a bronze hub and revolving in front of pole pieces B B'. The magnetic circuit is made up of the casting C, the air gap and the cover plate C'. The castings C and C' are bolted together and carry

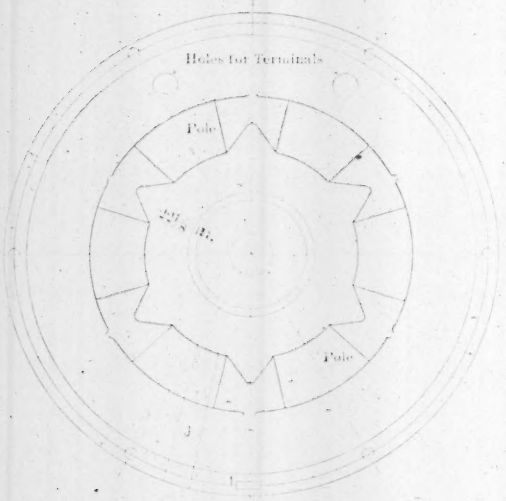


FIG. 3 LEFT HALF OF FIELD CASTING SHOWN IN SECTION IN FIG. 2

the exciting coil D and the bearings E and E'. The magnetic yoke, made up of castings C and C' carrying the field coil and disc, is supported in ball bearings, and is prevented from rotating with the disc by the spring balance shown in Fig. 1. This latter measures the pull or torque between the rotating disc and the stationary yoke.

8 The magnetizing coil is encased in copper, the terminals being carried out through holes in the casting C, which are carefully sealed after the coil is in place.

9 The heat generated by the short circuiting of the eddy currents generated in the copper disc, is carried off by the cooling water which

enters through the base connection at *F* (Fig. 2) and passes up through the bearings into the field casting. It then passes out through openings which are not shown in the illustration. This water not only carries off the heat generated, but serves as a lubricant for the bearings. That which passes through accumulates in the central chamber *E*, and is discharged at the base of the machine through the drains *G G'*.

10 Fig. 3 is a detail drawing of the left half of the field casting *C*, shown in section in Fig. 2. It will be seen that there are six poles in the machine. The circulating water enters at *I* and leaves through the port at *J*. Similar ports are provided in the cover plate *C*, Fig. 2.

OPERATION

11 In operating, the engine under test is directly connected to the dynamometer shaft by means of some form of flexible coupling, the cooling water is turned on and the engine is started. After normal speed is reached, the load may be thrown on by energizing the field coil. The amount of current, and consequently the torque or pull on the spring balance is regulated by a rheostat connected in series with the coil. After running a few minutes, the quantity of cooling water is adjusted so that the temperature of the machine does not exceed 150 deg. fahr. In larger machines the coil may be wound with asbestos-covered wire and the temperature permitted to reach 212 deg., so that the cooling water is evaporated within the dynamometer. This reduces the quantity of cooling water required about 75 or 80 per cent.

12 The normal working temperature having been reached, the load on the machine remains absolutely constant, provided the line voltage is constant, for the mechanical friction, which is the bearing friction of the revolving disc, is small and practically constant, and changes in temperature due to changes in the supply of cooling water also affect the load on the dynamometer very little. The regulation by the rheostat is instantaneous and positive. When the dynamometer is driven by a smooth-running engine, the torque as indicated by the spring balance will not show a variation of $\frac{1}{8}$ lb., while the balance is sensitive to less than 1/16 lb. This indicates an accuracy that is not necessary even in the most refined testing work.

RELATION BETWEEN SPEED AND TORQUE

13 In the case of the present machine the torque is almost pro-

portional to the speed and is maximum at about 600 r. p. m. From this point the torque props off about 15 per cent at 1200 r. p. m., and remains almost constant from 1200 to 1500 r. p. m.

14 The torque depends upon the speed, number of poles, thickness of air gap, thickness of the copper disc, shape of the copper disc, and shape and spacing of the pole pieces. By varying the number of pole pieces, and the thickness of the copper disc, the point of maximum torque on the speed-torque curve may be shifted anywhere from 25 r. p. m. to 2500 r. p. m.

CONCLUSION

15 This type of dynamometer is well adapted either for the testing of high-speed motors with a wide variation in speed, such as the automobile engine, or for the testing of slow-speed apparatus having a small variation in the speed. It can be built in practically any size from 10 h. p. up. The principal disadvantage is the high initial cost, although this is not an item where serious and continuous testing work is going on, as in factories or in the laboratories of technical schools, for the labor saved and the increase in capacity resulting through the use of the machine will in a short time more than pay for the initial outlay.

16 The efficiency, which may be expressed as the ratio of the energy absorbed by the dynamometer, minus the energy supplied to the exciting coil, divided by the energy absorbed by the dynamometer, may be made anything up to 99.9 per cent and depends upon the weight of copper placed in the coil. Ordinarily the efficiency is made about 96 per cent, or 4 per cent of the power absorbed by the dynamometer is required in the form of electrical power for excitation.

DISCUSSION

THE HIGH-PRESSURE FIRE-SERVICE PUMPS OF MANHATTAN BOROUGH, CITY OF NEW YORK

By Prof. R. C. Carpenter, Published in the Journal for September

DISCUSSION AT ST. LOUIS

Horace S. Baker[1] presented some very complete notes on the proposed high-pressure system for Chicago, an abstract of which is given herewith. After telling of that city's need of a high-pressure system, Mr. Baker illustrated the effect of such an installation on insurance rates by citing the reductions brought about in other cities, as follows:

a Philadelphia, an initial reduction of 25 cents per $100, to be followed by a 10-cent reduction.

b Buffalo, a reduction of about 3 per cent for all buildings within 500 ft. of a fire boat pipe line.

c Manhattan Borough, New York, 10 and 15 per cent advances reduced to 5 per cent; 25 per cent advance on piers reduced to 5 per cent; storage warehouses reduced from 10 to 5 per cent; "sprinklered" risks reduced from 10 to 15 per cent.

d Brooklyn Borough, New York, 10 to 25 per cent reductions in high pressure zone.

e Coney Island, New York, 25 per cent reduction.

f Cleveland, 5 to 10 per cent reduction.

2 The costs of maintaining and operating the proposed system for Chicago should not be more than the following figures, and probably much less:

[1] Engineer, Department of Public Works, Chicago.

Operating costs of three pumping stations, including interest and depreciation	$180,000
Interest on cost of distribution system, 4 per cent of $3,000,000	120,000
Depreciation of distribution system, 2 per cent of $3,000,000	60,000
Maintenance of distribution system	50,000
	$410,000

TABLE 1 COST DATA

NAME OF SYSTEM	TYPE	PRESSURE AND CAPACITY PER MIN.	TOTAL COST EXCEPT DISTRIBUTION SYSTEM	ANNUAL OPERATING EXPENSE OF PUMPING STATIONS[1]	COST PER 1000 GAL. PER MIN. CAPACITY[1]	ANNUAL OPERATING COST PER 1000 GAL. PER MIN. CAPACITY[1]
Manhattan	Electric Centrifugal Pumps	300 lb. 30,000 gal.	$670,000	$139,250	$22,333	$4,642
Coney Island	Gas Engines Triplex Pumps	150 lb. 4,500 gal.	47,000	14,186	10,444	3,152
Philadelphia	Gas Engines Triplex Pumps	300 lb. 9,100 gal.	260,000	11,978	28,571	1,316
San Francisco, Estimate 1	Steam Turbines Centrifugal Pumps and boiler Plant Oil Fuel	300 lb. 20,000 gal.	622,228	34,630	31,111	1,732
San Francisco, Estimate 2	Gasolene Engines Turbine Pumps Rope Drive	300 lb. 20,000 gal.	737,848	30,595	36,892	1,529
Hartford, Estimate 1	Steam Turbines Centrifugal Pumps Coal Fuel	300 lb. 12,600 gal.	257,620	45,320	20,466	3,597
Hartford, Estimate 2	Gas Engines Triplex Pumps	300 lb. 12,600 gal.	377,905	8,648	29,992	686
Chicago, Estimate	Steam Turbines Centrifugal Pumps	250 lb. 10,000 gal.	263,005	37,400	26,300	3,740
Chicago, Estimate	Gas Engines Triplex Pumps	250 lb. 10,000 gal.	248,112	24,626	24,811	2,463
Chicago, Estimate	Electric Motors Centrifugal Pumps	250 lb. 10,000 gal.	122,882	57,700	12,288	5,770

[1] Exclusive of Interest and Depreciation.

TABLE 2 APPROXIMATE ESTIMATE OF COST

STEAM TURBINE PUMPING STATION, 10,000 GALLONS PER MIN. PRESSURE 250 LB. PER SQ. IN.

1	Excavation:		
	Pump pit	2300 cu. yd.	
	Boiler room	3865 " "	
	Stack	565 " "	
	Conveyor tunnel	70 " "	
		6800 cu. yd. at $1	$6,800
2	Concrete:		
	Retaining walls for pump pit	616 cu. yd.	
	Boiler room foundations	453 " "	
	Stack foundations	430 " "	
	Pump house foundation	101 " "	
		1600 cu. yd. at $7	$11,200
3	Building:		
	Pump room, 60 ft. by 54 ft. = 3240 sq. ft.		
	Boiler room, 78 ft. by 84 ft. = 6552 " "		
		9792 sq. ft.	
	Assume 10,000 sq. ft. by 30 ft. = 300,000 cu. ft. at 15 cents		45,000
4	Foundations for pumps and turbines, 150 cu. yd. at $10		1,500
5	Four 2500-gal. centrifugal pumps at $5,000		20,000
6	Four 600-h.p. steam turbines at $12,000		48,000
7	Boilers, 2400 h.p. at $15		36,000
8	Chain grates, hoppers, conveyors, etc		15,000
9	Stack		8,000
10	Suction piping from city main and tunnel		6,500
11	Discharge piping		5,000
12	Steam piping		7,500
13	Condenser		6,200
14	Boiler auxiliaries, heater, purifier, pumps, etc		9,000
15	Two 20-in. venturi meters and recorders		3,000
			$228,700
	Add 15 per cent		34,305
			$263,005

3 In the light of current practice as shown in Table 1, it seems advisable to consider and estimate on the following types of pumping stations:

a Steam turbines and centrifugal pumps.
b Electric motors and centrifugal pumps.
c Gas engines and triplex pumps.

TABLE 3 APPROXIMATE ESTIMATE OF OPERATING EXPENSE

FOR STEAM TURBINE STATION, 10,000 GAL. PER MIN. AT 250 LB. PRESSURE

1	Interest, 4 per cent of $263,005		$10,520
2	Depreciation, 4 per cent of $263,005		10,520
3	Coal:		
	200 hr., 5 tons at $2.50		
	8560 hr., ½ ton at 2.50		13,200
4	Oil, waste and supplies		1,500
5	Repairs		2,500
6	Labor:		
	Men, cost per annum three 8 hr. shifts:		
	1 engineer	6600	
	1 oiler	4500	
	1 fireman	3000	
	2 coal passers	5400	
	1 janitor	700	20,200
	Total		$58,440

4 For the purpose of estimate it seems proper to assume a station of a capacity of 10,000 gal. per min. against 250 lb. pressure, the working pressure to be probably 150 to 200 lb. To avoid the crippling of a station by the shutdown of any unit it seems advisable to consider units of 2500 gal.

5 In discussing the various types of installations proposed, Mr. Baker cited the advantages of each type. The direct-acting duplex pumps are rugged and ready for immediate service, but their steam consumption is large. The independent boiler plant necessary, moreover, would be costly to build and to operate.

6 The gas-engine station has the advantage of lower first cost, and no cost for power when not in operation. Though failure of the gas supply is unlikely, gasolene could be used with a change of adjustment, or by running normally on illuminating gas with low compression, which would be somewhat uneconomical. A gas-producer plant might be installed, though this is somewhat open to the same objection as the boiler plant.

7 Though electric motors are supplied from an outside source, the large number of generating stations and feeders makes the electric supply as reliable as the gas supply. The first cost and the operating expense of an electric station are low, though the standby charge is high.

8 Connecting the system to standpipes and sprinkler system

TABLE 4 APPROXIMATE ESTIMATE OF COST

APPROXIMATE COST OF GAS ENGINE STATION, 10,000 GAL. PER MIN., 250 LB. PRESSURE

1	Excavation:		
	Retaining wall	68,400 cu ft.	
	Main pit	58,089 " "	
	Engine foundations	5,096 " "	
	Pump foundations	7,056 " "	
	Tunnel	5,496 " "	
		144,137 cu. ft.	
		= 5,339 cu. yd. at $1	$5,339
2	Concrete:		
	Retaining wall	11,520 cu. ft.	
	Retaining wall footing	23,040 " "	
		34,560 cu. ft.	
		= 1,280 cu. yd. at $7	8,960
3	Building: 82 ft. by 79 ft. = 6478 sq. ft. by 30 ft. = 194,340 cu. ft. at 15 cents		29,151
4	Foundations for pumps and engines, 150 cu. yd. at $10		1,500
5	Seven 1500-gal. triplex pumps, for 250 lb. pressure at $8900		62,300
6	Seven 300-h.p. gas engines at $10,000		70,000
7	Freight and erection		7,000
8	Suction pipes from city main and tunnel		6,500
9	Water discharge pipes		5,000
10	Gas connections		8,000
11	Air compressor plant		2,500
12	Gasolene tanks and piping		3,500
13	Two 20-in. Venturi meters and recorders		3,000
			$215,750
	Add 15 per cent		32,362
			$248,112

TABLE 5 ESTIMATE OF OPERATING COST

GAS ENGINE STATION

1	Interest, 4 per cent on $248,112		$9,924
2	Depreciation, 4 per cent on $248,112		9,924
3	Gas: 200 hr. at 18 cu. ft. per h.p. at $0.85 per M		6,426
4	Labor: 3 engineers at $2200 = $6600		
	6 asst. engrs. at 1500 = 9000		
	1 janitor at 600		
			16,200
5	Oil, waste and supplies		1,000
6	Repairs		1,000
	Total		$44,474

TABLE 6 APPROXIMATE ESTIMATE OF COST

ELECTRIC PUMPING STATION, 10,000 GAL. PER MIN. PRESSURE 250 LB. PER SQ. IN.

1	Excavation:		
	Pump pit	63,936 cu. ft.	
	Retaining wall footings	8,640 " "	
	Pump foundations	2,048 " "	
	Building wall	1,692 " "	
		76,316 " " = 2,826 cu. yd. at $1	$2,826
2	Concrete:		
	Wall of pump pit	15,264 cu. ft.	
	Footings	7,892 " "	
	Bldg. foundation wall	920 " "	
	Bldg. foundation footings	329 " "	
		24,405 cu. ft.	
		= 904 cu. yd. at $7	6,328
3	Building:		
	Pump room, 36 ft. by 56 ft. = 2016 sq. ft.		
	Switch room, 16 ft. by 56 ft. = 896 sq. ft.		
		2912 say 3000 sq. ft. by 30 ft. = 90,000 cu. ft. at 15 cents	13,500
4	Foundations for pumps and motors, 150 cu. yd. at $10		1,500
5	Four 2500-gal. centrifugal pumps at $5000		20,000
6	Four 600-h.p. 3-phase induction motors at $10,800		43,200
7	Suction piping from city main and tunnel		6,500
8	Discharge piping and valves in station		5,000
9	Switchboard and wiring in station		5,000
10	Two 20-in. Venturi meters and recorders		3,000
			$106,854
	Add 15 per cent		16,028
	Total		$122,882

in buildings had been recommended in Chicago and is the practice in Winnipeg, Man., and Providence, R. I., and also with the gravity system in Newark, N. J., Worcester and Fitchburg, Mass. The fire systems of New York City and Philadelphia are not connected in this way. The objection to these connections is that great loss of water might result from broken pipes in the buildings. This could be avoided, however, by placing a controlling valve in a brick chamber outside the curb.

TABLE 7 APPROXIMATE ESTIMATE OF OPERATING EXPENSE

ELECTRIC PUMPING STATION

1	Interest, 4 per cent of $122,882			$4,915
2	Depreciation, 4.3 per cent of $122,882			5,284
3	Power bill:			
	Ready-to-serve charge, $25 per kw. = $37,500			
	$0.005 per kw. per hr., 200 hr. of full load $1,500			39,000
4	Labor, 3 shifts:			
	3 engineers	at $2200	$6600	
	6 asst. engineers	at 1500	9000	
	1 janitor	at 600	600	16,200
5	Miscellaneous: oil, supplies, etc			1,500
6	Repairs			1,000
				$67,899

TABLE 8 ESTIMATED COST OF PROPOSED CHICAGO SYSTEM

MAINS, VALVES AND HYDRANTS

DISTRICT NO.	COST
1	$477,508
2	329,321
3	152,018
4	128,457
5	109,178
6	314,569
7	82,791
8	178,420
9	146,432
10	118,916
11	113,268
12	85,852
13	75,918
14	175,811
Total	$2,488,459
Engineering and contingencies	373,269
	$2,861,728
4 stations at $250,000 =	1,000,000
	$3,861,728

No allowance made for land.

River crossings are assumed to be made as follows: (*a*) North branch in present Grand Ave. water pipe tunnel; (*b*) Main River in proposed LaSalle St. water pipe tunnel, to be built by Chicago Railways Company; (*c*) South branch in present Harrison St. water pipe tunnel.

TABLE 9 HIGH-PRESSURE FIRE SERVICE IN THE UNITED STATES

City	Estimated Population	Date of Installation	Source of Pressure	Gal. Per Min.	Max. Pressure, Lbs.	Lineal Ft. of Mains	Sizes of Mains, Ins.	No. of Hydrants	Total Cost of System	No. of Acres	Cost Per Acre	Connection With Building	Effect on Insurance Rates
Atlantic City	40,000	Proposed	1 Station Elec. Turb. Pumps	7,000	225	38,590	8–14	82	$187,272	306	$612		
Baltimore	575,000	Proposed	Pump. Sta.			75,900	10–20		*397,999	360		Standpipes on Buildings	
Boston	620,000	1898	Fire Boat	6,000	200	4,700	12	14	30,080	65	463		
Brooklyn	1,400,000	1906	2 Pump. Sta. Elec. Turb. Pumps	32,000	300		8–20		1,384,500	1420	975		
Buffalo	420,000	1897	3 Fire Boats		300	12,756	12						Reduction of $0.30 per $1000
Chicago	2,229,000												
Cleveland	480,000	Constructing	2 Fire Boats to Have Pump. Sta.	10,000	300	32,524	8–20	96	*170,000	338		May have Connection with Auto. Sprinklers.	Reduction of $0.80 per $1000 Prop.
Coney Island		1905–6	1 Station Gas Triplex Pumps	3,600	150		8–16		90,000	147	612		Reduction of 25 %
Detroit	380,000	1893	2 Fire Boats	10,000	210	25,831	8–10	95		356	135		Probably has Prevented Increase
Fitchburg	33,000		Gravity†		180	28,250	8–16		50,000	346	144	Boiler Feed, Elevators and Sprinklers	Prevented Increase
Hartford	98,000	Proposed	1 Station	10,000	300	53,430	8–24	198	796,277	731.3	1089	No open Connection	
Lawrence	75,000	1906	Gravity †		134	10,200	10–12	39		120			No change
Milwaukee	340,000	1889	3 Fire Boats	15,000	250	45,717	6–12	183		630			10% Reduction

Newark.....	290,000	1905	Gravity	3,500	165	15,000	20–30	52	135,000	303	446	Some Connection	10% Reduction
New York..... (Manhattan)	2,100,000	1908	2 Stations Elec. Turb. Pumps	30,000	300	.....	12–24	1200	3,950,400	1430	2763	Water Curtains Provided for	No change
Philadelphia.....	1,500,000	1903	1 Station Gas Triplex Pumps	9,100	300	35,300	8–16	166	700,000	512	1367	None on or in Buildings	Penalty of 25% Removed‡
Providence.....	200,000	1897	Gravity †	3,472	116	29,000	12–24	89	143,136	358	400	5 Automatic Sprinklers	No change
Rochester.....	185,000	1874	2 Stations Elec. Turb. Pump, Steam Turb Turb. Pump	9,000	140	102,960	4–20	.....	.....	.....	.....	Some Connection	Graded Reduction
Toronto.....	215,000	Constructing	1 Station Elec. Turb. Pump	14,000	300	40,000	8–20	.....	,500,000	287	1742	Considering Connection	Uncertain
Winnipeg.....	110,000	1908	1 Station Gas Producer Gas Eng., Tripl. Pumps	10,800	300	15,840	8–20	.....	650,000	275	2364	Connection with Auto. Sprinkler	Uncertain
Worcester.....	138,000	.....	Gravity†	.....	165	100,320	8–30	.....	.....	1380	.....	Elevators	No change

* Exclusive of pumping station and equipment.

† System consists of extension of pipes from high service into district covered by low service.

‡ Board of Fire Underwriters have voted to reduce rates to the amount of 10 cents per $1000 = a total of $40,000, if extensions costing $150,000 are made to the system.

NOTE:—This table is taken from the report on the proposed high-pressure fire system for Hartford, Conn.

EDWARD E. WALL[1] outlined the proposed fire system for St. Louis, which contemplates the installation of six or eight 5-stage centrifugal pumps, electrically driven, at a station on Chestnut St., from which the fire service mains will radiate north, south and west. The supply for these pumps will be taken from the distribution system, a 36-in. main being laid directly from the Bissell's Point pumping station to the Chestnut St. station, and connected to the present distribution system by a number of by-passes. Connections will also be made between two 20-in. mains on Fourth and Seventh Sts., to the supply for the pumps, so that in case of failure of the 36-in. main, the pumps may be supplied from this source.

2 It would be practicable to draw the fire pump supply directly from the Mississippi River by building an intake, but this would probably cost more than the laying of the 36-in. main, and would necessitate a charter from the Government. It would also raise the question of obstructing navigation, since it would be necessary to carry the construction well out into the channel, to insure an ample supply of water. Supply from the river direct would also preclude all connection with the distribution system, as it would be unwise to risk the contamination of the city's water supply by river water.

3 The pumping capacity of the station at Bissell's Point will be over 100,000,000 gal. of water every twenty-four hours, which is more than twice the amount ordinarily consumed; the excess being sufficient to supply more than 30 fire-streams through 3-in. hose continuously, assuming 300 lb. pressure at the fire pumps.

4 The 5-stage centrifugal pumps proposed for the Chestnut St. station will have a capacity of 150,000 gal. per hr. each, against a pressure of 300 lb. per sq. in. It is proposed to connect the station with the power plants of the Union Electric Light and Power Company and the United Railways, so that two sources for power will be available.

5 The three discharge mains from these pumps will be 24 in. in diameter, the district supplied by them to be gridironed by a system of 12-in. mains laid on the enclosed streets and occasionally connected, at crossings only, by by-passes, that the breakdown of one main may not necessitate the cutting out of any other line. The pipe used will be cast iron, extra heavy, with bell and spigot joints, double-grooved. All fire-hydrant leads will be 8 in. in diameter.

6 The system will be under the ordinary distribution pressure

[1] Asst. Water Commissioner, St. Louis.

when the fire pumps are not in use, so that for small fires the hydrants will be available for use; when the fire pressure is put on the system, the check valves on the by-passes will prevent additional pressure from coming on the distribution system.

7 While the arrangement of machinery for the pumping station, and the details of operation, have not been definitely decided upon, it is possible that gas engines may be used instead of electric motors. The questions of automatically starting and stopping the pumps, maintaining the pressure during a fire, and the general details of operation of the station, as well as the minor points of weight of pipe, design of hydrants, etc., have all to be worked out. It is estimated that the cost of this system will approximate $3,000,000.

H. C. HENLEY,[1] speaking on the advantages of high-pressure fire systems, said that they were chiefly valuable for the numerous powerful streams which can be quickly brought into service and concentrated to advantage. For the prevention of conflagrations and for keeping serious fires from spreading, more powerful streams are needed than can be supplied by portable fire engines without considerable delay. To obtain such streams from fire engines, it is necessary to "siamese"

PRESSURE REQUIRED AT HYDRANT TO OVERCOME FRICTION LOSS

Hose Diameter		2½ IN.		3 IN.		3½ IN.	
Hose lines		Single	Siamesed	Single	Siamesed	Single	Siamesed
Smooth bore nozzle		1¼ in.	2 in.	1½ in.	2 in.	1¾ in.	2 in.
Length of hose line, ft.	100	121	139	92	101	84.5	88
	150	139	170	99.5	113	87.5	93.5
	200	158	201	107	125	91	99
	250	176.5	232	114.5	137	94.5	104.5
	300	195	263	122	149	98	110
	400	232	325	137	173	105	121

For the 2-in. nozzle it is assumed that two hose lines of the length given are siamesed together.

two or more lines into one nozzle, requiring considerable time; and if a change in the location of engines becomes necessary, considerable time is again lost in re-assembling the hose lines.

2 The high-pressure system permits the use of hose of large diameter—3 in. and 3½ in.—and direct connection to hydrants furnishes a supply to nozzles of large area, without the necessity of siamesing

[1] Chief Inspector, St. Louis Fire Prevention Bureau.

two or more hose lines. The 2-in. nozzle is best adapted for use with high-pressure systems, this nozzle, under 75 lb. nozzle pressure, discharging approximately 1000 gal. per min. A nozzle of this area provides very effective service, as the loss of pressure, due to friction in fire hose, decreases as the area of the hose is increased. The data given in the table are derived from experiments by John R. Freeman, and show the pressure required at the hydrant to overcome friction loss in hose streams of various lengths and maintain 75 lb. nozzle pressure, the nozzle being at the same level as the hydrant.

3 High-pressure systems should be considered as auxiliary protection and there should be no attempt at abandonment of engines or other apparatus.

4 Direct connection from a high-pressure system to interior standpipes, sprinkler equipments and open sprinkler systems, should be made through siamese connections and not through direct pipe connection.

5 The inability of portable steam fire engines to furnish a stream efficient to cope with serious fires is made apparent by tests made by the engineers of the National Board of Fire Underwriters. The steam fire engines for test were picked at random from the equipment of many of the best city fire departments in the country.

Number of engines tested	102
Nominal capacity, gal	69,800
Actual capacity, gal	55,900
Percentage of efficiency	80

In many cases the efficiency of individual "steamers" is less than 50 per cent.

EDWARD FLAD. It appears to me that a cast-iron pipe is rather dangerous for high pressure. A cast-iron pipe tested under 300-lb. pressure will often break at 75 lb. A wrought steel pipe is much more reliable, and if properly coated, should last 25 or 30 years under ordinary conditions. If steel pipe is absolutely reliable we could afford to relay it at the end of 25 years rather than to use cast-iron pipe, which is liable to break.

2 In answer to a question by Mr. Flad as to the flexibility of the joint used in Baltimore, Professor Carpenter replied that it is flexible,

in the sense that it can be laid at an angle; it is not flexible as far as change of form is concerned.

H. S. BAKER asked what kind of steel pipe would be used in Baltimore, Professor Carpenter answering that it is extra heavy steel-welded pipe, $\frac{1}{16}$ in. thick, the ends being expanded into semi-spheres, an 8-in. or 12-in. pipe being expanded just enough to get a ring in it, and the whole is bolted on the outside by external bolts, very like a steam pipe.

PROF. H. WADE HIBBARD. It is a fact that a cast-iron water main has been in satisfactory use in city service for twenty years, and then a piece has blown out. It seems to me that the use of cast-iron pipe should be prohibited for this special emergency purpose of fire protection on account of its unreliability. In fact, in one of the high-pressure systems using cast-iron mains, leaks have been known to take place and the pumps to run for a considerable interval, some hours, I will say, and the pressure could not be maintained under test, until it was finally discovered that the water had been pouring out into a very large excavation and flooding it, unknown to those operating the pumping station. Steel will show approaching deterioration as cast iron will not.

2 Steel pipe ought to be good for thirty years of service. That period of service should be sufficient, and cities having such pipe should then be willing to replace it, having had more reliable protection during that period of years, than cast-iron pipe could possibly give.

H. C. HENLEY asked if there had been any attempt made to prevent the pipes from deteriorating through electrolysis, Professor Carpenter answering that the Baltimore system is a continuous metallic structure, from one end to the other, and he believed would be thoroughly protected from electrolysis; or at least, better than by any other system.

E. E. WALL. It is a fact that actually and not figuratively, steel pipe must be handled with gloves when it is laid, because the coating has to be very carefully preserved and can hardly be repaired if it is broken in handling before the pipe is laid. This is a very serious objection to the laying of steel pipe on account of exposure to corrosion after it is laid.

W. H. REEVES. Owing to the magnitude and prominence of these plants, the pump performances should be of interest to those desiring information on centrifugal and turbine pumping machinery. The highest achievement in the art of building machinery of this class is accuracy in design. Without accuracy in design it is not possible to secure the maximum efficiencies within reach. A closely designed pump should deliver exactly its contract number of gallons against the contract pumping head, and the capacity should not run over nor under. From a pump builder's point of view the misfortune of falling short of the contract capacity needs no discussion here, but the other misfortune of running over on capacity may not be so clearly understood. One effect of running over is an overload on the motor, engine or steam turbine driving the pump, and another result is that the average efficiency of the equipment in daily operation is below what it should be, for if it runs over in capacity its maximum efficiency does not occur at its contract capacity.

2 It will be noted that each of these pumps had a contract capacity of 3000 gal. per min., against a total head of 308.66 lb. per sq. in. Table 2 shows the performances of the five pumps at the South Street pumping station. This table does not show the averages, but it will be found that each pump averaged approximately 3761 gal. per min. against a mean total head of about 313.1 lb. per sq. in. Although the head was about 5 lb. above the contract condition, the pumps exceeded the contract capacity by about 25 per cent. This, no doubt, caused the motor overload mentioned in Par. 64. The contract conditions implied 540 h.p. actually delivered, and at the guaranteed pump efficiency 770 b. h. p. would be needed. The delivered work under test was 686 h. p., and according to the test efficiency of $72\frac{1}{2}$ per cent, 946 b. h. p. was used, that is, approximately 23 per cent excess motor load.

3 There appears to be no data on tests made at the contract conditions. As the pumps were tested at a great excess in capacity it is quite probable that the efficiency would have been lowered several points if the pumps had been throttled to the agreed capacity and head. The tests as per Table 2 show about 686 h. p. delivered and 946 b. h. p., or a pump loss of 260 h. p. For a considerable range it is probably safe to assume this 260 h. p. loss to be fairly constant. Assuming this to be correct and adding this loss to the 540 h. p. delivered represented by the agreed contract conditions, would give 800 b. h. p., thus showing a pump efficiency of but $67\frac{1}{2}$ per cent. If these pumps had been accurately designed, undoubtedly they would

have shown as high efficiency under the contract conditions as was obtained with excess capacity condition.

PROF. E. L. OHLE. There seems to be quite a difference in opinion among engineers as to the reasons for the variation in efficiency of the pumps when working singly and in multiple. It seems to me that the reason is the one suggested by Professor Carpenter. It is practically impossible that all should work at the same speed, as they are independently driven. If then the pressure in the main should exceed the pressure which any pump was capable of delivering, the runner of that pump would simply revolve without delivering any water. This seems to be borne out by the experience of one pump builder, as stated by J. J. Brown.

THE AUTHOR. The discussion of the paper has been so voluminous that there is really but little needed from the author. In most of the discussion additional information of value has been contributed which I am sure will be appreciated by members of the Society.

2. The difficulties in connection with an installation of the kind described in the paper, involving a complete system of piping and hydrants capable of withstanding high pressures, as well as the necessary pumping machinery, are well brought out. I think the general conclusion will be that the piping difficulties to be overcome, especially when cast iron is employed, are very serious and require special skill and the best of material. Attention has also been called to the fact that the city of Baltimore has adopted a system in which steel pipe is employed in order to overcome the difficulties due to the breakage of cast-iron pipe.

3 The discussion has disclosed the construction of several stations in which the motive power has been obtained from gas engines, and the advantages, disadvantages and expense of such installation.

4 It is pointed out that although the centrifugal pumps are capable of operation at the high efficiencies shown by the paper, yet at the lower heads at which they are frequently operated the efficiency would be less. I do not believe there is any serious commercial disadvantage because of that fact, since it is true that the cost of operation of a fire station is principally due to other items than the cost of power. A fire station is required to be, above all things, reliable, and it is of very little importance whether or not the pumping be done under the most economical conditions for the reason that the total cost of pumping is only a small portion of the operating expense.

5 It is claimed by one of the discussors that the test should have

been made by the city at the exact capacity called for and the efficiency should have been based on the result of such a test. This doubtless would have produced a lower efficiency than that obtained. In the light of the information now at hand, there would have been no injustice in such a requirement, but at the date of making the contract matters were different and such a requirement would have imposed a penalty on the builders, which would have been of no advantage to the city. The reason for that opinion is, that at the time of taking the contract the information regarding multi-stage pumps operating at high heads was quite meagre. Mr. Sando, the designer of the pumps, secured all the data he could both in this country and in Europe. The result of his investigation led him to believe that it was to the advantage of the city and of the builders to put in a pump of such capacity that it would surely meet the requirements in that respect. It was believed that this would result in a considerable increased capacity over contract requirements. The motors were designed with an equally liberal capacity so that the machine was intended, even in the beginning, to be capable of a continuous large overload. The statement that the motors showed any evidence of being overloaded is in error, possibly because a certain remark which I made was misunderstood. It strikes me that the city is the principal gainer by such a system of design and that as a consequence it owns considerable more pumping capacity than was called for in the specifications, and so far as I know, without extra cost.

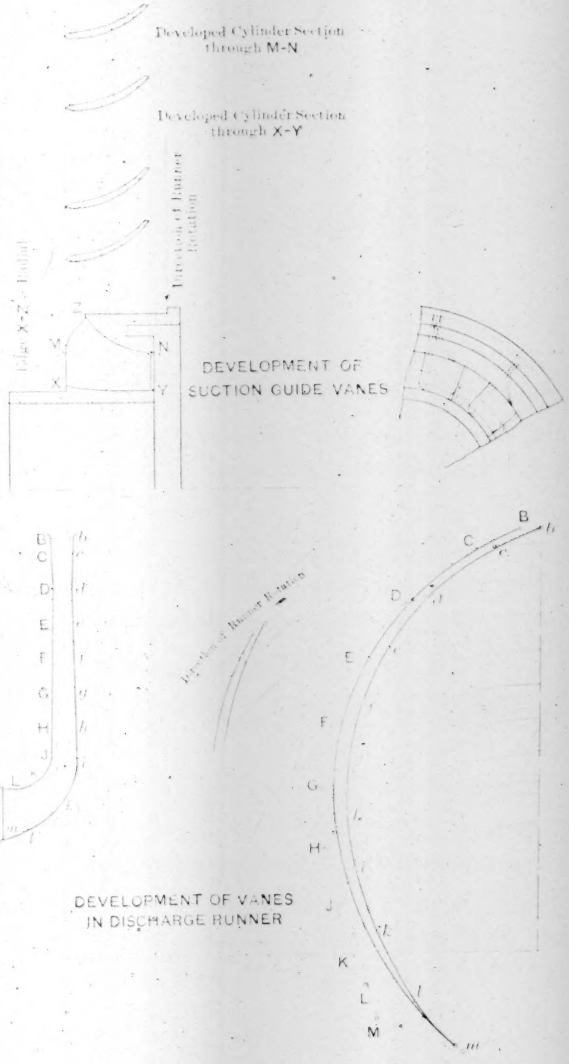
6 I believe that with the present data it would have been possible to design both pumps and motor to carry 25 per cent less load with the same efficiency as was obtained by the larger pumps and motors. In that case, a test at the specified capacity would have been a fair one.

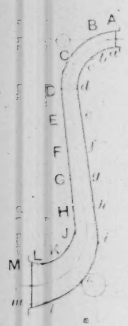
7 The interesting question brought out by these tests regarding the higher efficiency obtained with a single pump as compared with all the pumps discharging into the main, has not been satisfactorily answered. Such results, however, seem to have been noted by every engineer who has made similar tests.

8 In the paper I made one suggestion which I believe to be of importance. I have since thought that the variation in construction or in detailed shape of the discharge volume might possibly account for some of these differences. It is hardly possible that all the pumps can be made exactly alike and small inherent differences, which would be obliterated in the operation of all the pumps together, might account for the higher efficiency of the pumps operating singly. As

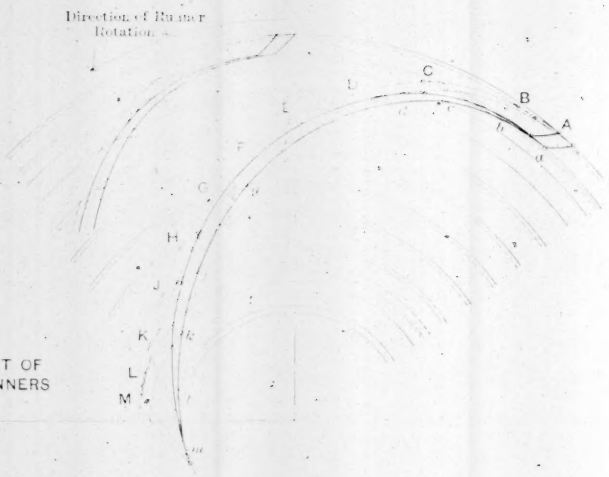
suggested by Mr. White, the measurements were of a character which did not consider the pipe resistances, and the figures given apply to the delivery from the pump before the water was subjected to pipe resistances in any case.

[The following curves show the development of the runners, guide wheels and guide vanes of the pumps installed in the New York high pressure pumping stations.—EDITOR.]

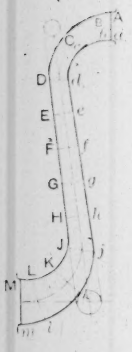

Developed Cylinder Section through M-N
Developed Cylinder Section through X-Y
DEVELOPMENT OF SUCTION GUIDE VANES
DEVELOPMENT OF VANES IN DISCHARGE RUNNER

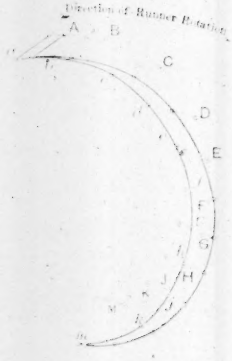


DEVELOPMENT OF VANES IN RUNNERS



DEVELOPMENT OF DISCHARGE GUIDE VANE





DEVELOPMENT OF VANES IN STATIONARY GUIDE WHEELS

LINESHAFT EFFICIENCY, MECHANICAL AND ECONOMIC

By Henry Hess, Published in the Journal for December

ABSTRACT OF PAPER

This is the description of a complete test of the relative efficiency of a lineshaft of $2\frac{7}{16}$ in. diameter, making 214 r.p.m., with bearing load due to the weight of the parts plus the tension of the belts subject to known stress by counterweighting, when running in ring-oiling babbitted bearings and when mounted in ball bearings.

Sixteen tests, each of forty minutes' duration, with belt tensions of 20 lb. to 90 lb. per inch width of single belt, were carried out. The intruments by which the electric energy consumed was measured, as well as all other instruments and the motor, were calibrated before and after the tests. The savings in power consequent on this change ranged from 14 to 65 per cent, with 36 and 35 per cent under average conditions of good practice, due to belt tensions of 44 lb. and 57 lb. per inch width of single belt respectively.

The paper gives data for determining the power savings that may be expected in various plants, as a percentage of the plain bearing shaft friction and as percentage of the total power consumption; also exact figures taking into account extra investment, depreciation, maintenance, interest on extra investment and power savings, which show that for the plant tested and described the savings represent 37 per cent per annum.

DISCUSSION

T. F. Salter. It has been long conceded that appreciable power economies were to be secured through the use of ball or roller bearings in place of plain bearings.

2 However, data which would enable the engineer to determine what savings could be expected in specific installations have been meagre as to quantity and sometimes of a questionable quality. The results obtained by the author are valuable, and are such as to encourage the use of bearings which substitute rolling for sliding friction. The following cases show the economy obtained by the use of roller bearings.

3 A Pennsylvania shoe manufacturer, with an electrically driven shop, found himself compelled to add considerable new equipment in

departments where the motors used were already overloaded. He concluded that new and large motors were necessary, but before taking action, he consulted engineers who after investigation recommended that roller-bearing hanger boxes be purchased and the old motor equipment retained. One department required 68 h.p., with babbitted boxes. The application of steel roller-bearing hanger boxes reduced the power consumption to 50 h. p., a saving of 18 h. p., or nearly 24.5 per cent, and enabled the old motors to drive the new equipment, with a small reserve for additional equipment.

4 A Baltimore belting company had a 4 7/16-in. bearing which gave a great deal of trouble through overheating. Oil bath and water jackets were tried with more or less success. A roller bearing was tried, proved successful, and forty additional bearings of various sizes were installed.

5 A wire company of Worcester, Mass., equipped their entire plant with roller bearings and have reported a 65-per cent reduction of friction load.

6 A friction disc transmission was designed by a New Jersey corporation, the requirements being that the driven shaft revolve at a constant speed. The driving shaft was subject to slight variations in speed which were to be compensated for by automatically moving the friction wheel across the face of the friction disc. The driven shaft was thus required to move laterally about 1½ in., and to rotate at 500 r.p.m. Plain bearings with sight-feed lubrication could not be used because of their resistance to lateral motion. A special ball bearing was designed to permit a free radial and lateral movement of the shaft, resulting in an extremely sensitive and satisfactory device.

7 Roller thrust bearings are widely used wherever a thrust load or pressure parallel to the axis of a shaft is to be carried. Practically any combination of load and speed can be provided for. Nearly three years ago a bearing of this type was built for a Pittsburg steel company to operate under a pressure of 1,500,000 lb. at 100 r.p.m. As a matter of fact it carried 1,477,650 lb., applied by hydraulic pressure of 1200 lb. per sq. in. on a 32-in. piston. There was recently delivered to the same company a set of bearings the specifications of which required that they be capable of carrying 2,000,000 lb. or 1000 tons at 100 r.p.m.

8 These bearings have been applied with signal success on apparatus such as vertical hydro-electric generators, synchronous converters, frequency changers, etc., and for this work are rapidly displacing the high-pressure oil thrusts. The advantages of roller bearings are prac-

tical indestructibility, and economy of floor space (doing away with pressure pumps, accumulator, and a mass of piping required with pressure thrust); they require little attention.

9 On an installation such as a hydro-electric generating unit, it is difficult to carry on tests which would indicate by electrical instrument reading the efficiency of thrust bearings. This is due to a number of losses, the values of which it is almost impossible to determine; for instance, the loss in guide bearings, windage, variation in load on thrust bearing occasioned by fluctuations of gate openings, etc. Laboratory tests have enabled the manufacturer to be reasonably sure of the possible efficiencies which could be secured. Data obtained in this way are not as acceptable to engineers in general, however, as results secured through actual practice.

10 Believing that calculations could be made which would closely indicate the efficiency of this type of bearing, tests were made in which the rate of flow of the oil, the temperature of the oil, and the revolutions per minute of the bearing, were carefully recorded. The load was estimated and might have varied, thus affecting results. Two machines were tested, each test lasting about a week. Readings were taken at intervals of ten minutes.

11 The bearings tested carried an estimated load of 140,000 lb., at a speed of 250 r.p.m.; the temperature rise was 50 deg. fahr.; the flow of oil was $11\frac{1}{4}$ quarts (18.8 lb.) per min. From the data obtained the coefficient of friction was calculated to be 0.0016 or 0.16 of 1 per cent.

12 In the tests referred to, the heat loss, due to radiation from the oil casing of the bearing, was calculated to be 2 per cent of the total heat generated. Another test was made later with the oil casing jacketed with asbestos and the results showed a difference of 2.74 per cent.

13 These figures may be somewhat low; laboratory tests indicate that they are. I believe, however, that with a bearing of this type designed to meet the conditions of load and speed under which it is to operate, a coefficient of friction of less than 0.0025 can be obtained readily.

C. A. Graves. In tests made on something over two hundred different line shafts in various industries, I have found that a unit termed "watts per bearing" is best suited to making comparisons. This unit was obtained as follows:

2 Tests were made, stopping all the machines connected to the

shafting and measuring the power required to run the motor and shafting. The main motor belt was then taken off and the power required to run the motor free was found. The hanger bearings were counted and also the loose pulleys over which belts were passing. The difference in power, measured in watts between the shafting running free and the motor running free, was divided by the number of hanger and loose pulley bearings.

3 It developed that, on the average, loose pulleys and the hanger bearing of about the same size took approximately the same amount of power, so that the sum of the loose pulleys and hanger bearings was called the "bearings." These tests were tabulated, first, by class of industry or business, and then according to the size of the shaft. For instance, in fifty tests in machine shops, with speeds ranging from 150 to 300 r.p.m., the average power absorbed by the shaft is 49 watts per bearing. Other tests gave results shown in the table.

No. of Tests Made	Size Shaft Ins.	R.P.M.	Power Consumed Average Watts per Bearing.
43	1	400	27.1
21	1¼	320–400	66.8
38	2	190–400	99.1
4	2½	200–250	108

One-inch shaft means 1 in. or 1 1/16 in.

4 We were fortunate in having eight different shafts equipped with roller bearings and loose pulleys. It was found that with the shafts running from 108 to 300 r.p.m., 22 watts per bearing were required, with roller bearings on a 2-in. shaft. Taking the author's figures of tests, 3 *A* would give 5.25 watts per bearing, while 4 *A* would give 62.0 watts per bearing.

5 The author might have mentioned an additional saving obtained by using ball bearings, as smaller motors may be used to drive the shaft, thus reducing the fixed charges.

C. J. H. Woodbury. Without questioning the general conclusions of the author, I wish to inquire if the three per cent coefficient of friction referred to in Par. 31 was derived from his experiments or from other sources. The friction of a lubricated bearing varies according to the temperature of the bearing and the pressure upon it. Different oils also give different results. With light pressures, the vis-

cosity of the oil plays a large part, so much so that if the film of oil is thick, the internal resistance from the fluid friction among the particles of this oil constitutes a large element.

2 Under heavy pressures the film of oil becomes thinner, the resistance due to its internal viscosity becomes diminished and the frictional resistance of the whole bearing approaches a direct ratio of the pressure upon it. In other words, the coefficient of friction becomes very nearly constant and slightly diminishes with increased pressure as long as the lubrication is sufficient to prevent the material of the two surfaces from coming into contact with each other, after which the frictional coefficient increases, although it may not reach the conditions of a hot bearing.

WALTER FERRIS. The coefficient of friction of railway journals is extremely low. Without being sure of the accuracy of the statement, I believe it is nearly always below one-half of one per cent, and approaches one-quarter of one per cent. Under these circumstances, granting for the moment the correctness of the statement, the saving of friction due to the ball and roller bearings would have to be balanced carefully against additional complication, first cost, and delay in making repairs.

FRED J. MILLER. The author has given no description or drawings of the bearings. The language of the paper will apply quite generally to ball bearings, whereas I understand that the test was made with specific ball bearings which had been in use for five years. I think we should have all the specific information about these bearings—including drawings—that the author is inclined to give, and a statement of the degree of refinement necessary in the making of the bearings in order to get these results.

ARTHUR C. JACKSON. An advantage of ball bearings over plain bearings is that the speed of the shaft can be decidedly increased, permitting a reduction in the weight of the shaft and the driving pulleys, and reducing windage and other losses. The smaller driving pulleys will give an increased arc of contact for the belt on the driven pulley. In my experience in driving high-speed machinery, increasing the speed of the line shaft, which can be accomplished by the use of ball bearings, has a distinct advantage.

CHAS. D. PARKER. The value of the ball bearing or roller bearing seems to be conceded in a general way, but its application imme-

diately brings up the question of excessive cost, so that it is hardly considered in many cases. Data of the sort given in the paper should be highly valuable as giving confidence to engineers in recommending the use of ball bearings on a large scale, even though the cost may be high. The question cannot be decided by a single experiment. Several experiments, including tests on a shaft 400 or 500 ft. in length, would be even more valuable, especially if made on bearings that have had a few years' service under ordinary care.

2 It might be of interest to know whether the apparently high cost of ball and roller bearings is due to the high cost of manufacture or to large selling expense, which we may expect to be reduced with a more general demand for the goods.

3 With the general introduction of electric-motor drive, the belt drive from line shafts has become somewhat old-fashioned. However, as the motors have large factors of inefficiency, if the efficiency of the line shaft belt drive can be greatly improved by the use of ball bearings, it would be of interest to know to what extent this can be done. It would probably be shown that the older method is still the more economical method in a great many instances.

OLIVER B. ZIMMERMAN. I would like to ask Mr. Hess if he has considered the application of ball bearings to countershafts which do not run the same proportion of time as the line shaft. What would be the relative return on the investment in that case, as compared with the line shaft itself? Furthermore, would it be advisable to lengthen the line shaft when the ball bearings are used; for instance, in group driving, would it be an advantage to use a line shaft 90 ft. or 100 ft. in length, as compared with a group of machines driven from 60 ft. of line shafting?

W. F. PARISH, JR. Mr. Hess's paper brings out an important point usually overlooked in comparative tests requiring great accuracy, namely, the influence of temperature and relative humidity on the power delivered, by causing variations in belt tension.

2 For comparative tests made under work-shop conditions it is advisable to have the belts made up half of cotton and half of leather, thereby eliminating the effect of humidity, which may cause variations of 12 per cent in the power delivered.

3 An English firm five years ago purchased a cotton belt to drive a dynamo, but this belt was not equal to the speed and power required of it, so a leather belt was substituted. It was decided to use the cot-

ton belt on one of the main mill drives, but it was found to be much too short. So a piece of leather belt was spliced in, the whole being, when finished, half leather and half cotton. A casing was built under it, as it was low down and in a dangerous position. The manager was annoyed to find that this casing had been built too close to the belt, no allowance being made for sagging.

4 The dampness greatly affected the leather belt, as the drive was in a low part of the mill, but the casing under the patched belt was never altered. The length of this belt never varies whether the weather is damp or dry and it is the best belt drive in the mill for steady work. Moisture has an opposite effect on leather and cotton, leather lengthening and cotton contracting with an increase of humidity, so that in the half-cotton and half-leather belt the weather effect is practically compensated for.

5 In Test 3 and Test 4, the average saving of power by using ball bearings instead of ring-oiling bearings is 36 per cent and 35 per cent, respectively, which is unusually good. It would be interesting to know what oil was used in the ring-oiling bearings during these tests and if the oil was new or old. With a very poor oil in the ring-oiling bearings the saving in power may be only partially caused by the change to ball bearings.

6 Oil and lubrication play a very important part in the economical distribution of power. Many power tests which I have made show that when very poor and cheap oil is used, a saving as high as 40 per cent can be obtained simply by using a better oil. Forty-two comparative power tests, made in small work shops or sections of large shops, show an average saving in power of 19 per cent, due to the use of a good and suitable oil. By using a good oil there will be but little increase in cost, as it can be used sparingly, so that the yearly cost for the better oil may be even less than for the poor oil. One test on a machine gear-driven by an electric motor showed a power saving of 55.5 per cent. by using a good oil instead of a poor oil and grease.

GEO. N. VAN DERHOEF. In the results of the tests summarized in Par. 41 of Mr. Hess's paper, the quantity of oil required to maintain ten 2 7/16-in. bearings is given as ½ pint a day, or 150 pints per year, which is equal to 18 ¾ gal. There is probably no make of self-oiling hanger on the market today that requires anything like this quantity of oil to maintain it. Three gallons a year for ten hangers would be ample allowance for even the poorest make.

2 The item of labor charged is two hours a week, which is also

excessive even if the enormous quantity of oil specified were used. As a matter of fact, three or four hours a year should be ample time to devote to the care and attention of ten 2 7/16-in. hanger boxes.

3 The allowance of twenty years for depreciation would seem fair for babbitted bearings, as probably all of us know of bearings running in daily service for a longer period. I would like to know if Mr. Hess has any figures showing ball bearings on line-shaft service for anything like this period. As I look at the matter—and I think others will agree with me—it is not so much a matter of a lower coefficient of friction as it is of the "staying properties" under practical conditions, as distinguished from a test experiment extending over a brief interval of time.

THE AUTHOR. Taking up the various points raised and the questions asked during the discussion, the author wishes to reply as follows:

2 *Percentage of Saving and Actual Saving.* A saving of power cannot be intelligently considered as a percentage of the entire driving power without full knowledge of the entire conditions. A given actual saving may be one per cent or ninety-nine per cent of a total. The saving in line-shaft journals when referred to the line-shaft loss is one ratio, and when referred to the total power consumption, is quite another ratio. So far as I am aware the literature on the subject quite generally refers to the line-shaft friction as a percentage of the total power consumption. That is misleading, since the percentage ranges from only sixteen or so in some textile mills to seventy or more in some of the rougher machine industries. In all probability the actual friction loss, bearing for bearing, does not vary in anything like so great a degree as sixteen to seventy per cent. The thing that is of real importance is not the ratio of the saving to a given whole, but the actual value of the actual saving.

3 *Estimating Power Losses and Savings.* Mr. Graves suggested that the power consumption of a bearing might be stated from experience in "watts per bearing." Such an expression would be convenient if it could be correctly applied; but the watt loss depends upon the coefficient of friction, the load and the surface speed. The coefficient of friction for a given type of bearing may be said to be fairly well known, or at least not to vary between very wide limits. That may also be said of the load; but the surface speed is made up of the shaft diameter, or rather the circumference, and the angular speed, both varying between very wide limits. So general an expression is therefore hardly possible, nor is it necessary.

4 For any given installation, the shaft diameter and speeds are known; the loads are due to the definitely determinable weight of the shaft, pulleys and belts, and to the belt pull, the last-named of which should not be allowed to exceed 60 lb. per in. width of single belt, while it certainly will rarely fall below 40 lb. The coefficient of friction for plain bearings may range from 2 to 8 per cent, with 3 per cent a very fair and general value, and $\frac{1}{2}$ per cent for ball bearings. A rise to $\frac{1}{4}$ per cent for ball bearings would indicate a poor quality of bearing.

5 An actual calculation, using the known constants of the installation in question, will always give closer results than the use of any general expression, necessarily much less accurate, such as "watts per bearing." In Par. 32 the expression for kilowatts is given as

$$Kw = 0.000,0059\ L\ d\ s\ \mu$$

or

$$\text{watts} = w = 0.000,000,0059\ L\ d\ s\ \mu$$

which may readily be converted to the convenient form

$K w_y$ = watts per bearing for year of 3000 hours

$$K w_y = 0.000,001\ L\ d\ s\ \mu$$

6 Mr. Graves has found the "watts per bearing" to range from 27.1 to 108 in 106 tests of plain bearings. The measured losses of the test cited in the paper are under average conditions of belt pull. For the usual belt load, Test 3 and Test 4 show for the ten plain bearings (see table in Par. 33) losses in kilowatts of 0.350 and 0.405, and for the ball bearings 0.018 and 0.020, or in watts per plain bearing 30 and 35, and for ball bearings 15 and 18.

7 Mr. Graves' four tests of a 2 7/16-in. line shaft at 200 to 250 r.p.m. may be fairly compared with the author's tests of a 2 7/16-in. line shaft at 214 r.p.m; Mr. Graves' result of 108 watts per bearing, as against the author's of 30 to 35, shows how unsafe a general wattage figure is. Changing the coefficient of friction from the 3 per cent found to be approximately correct for the test cited, to 10 per cent, would raise the 30 watts per bearing to Mr. Graves' 108 watts per bearing. In reality the tests cited by Mr. Graves are confirmatory of the author's, since the former range from 27 to 108, proving that the author's values of 30 to 35 for correct belt loads and 22 to 46 for extremely light and extremely heavy loads, represent an average of good practice.

8 *Indirect Economies.* Mr. Graves has suggested that the mounting of line shafts on ball bearings will reduce the sizes of the

motors required to drive the shafts. While that is obvious, the consequent economy is greater than is at first apparent. A motor must always be selected of sufficient size to perform its work safely. As the frictional resistance of a plain bearing line shaft is apt to vary between very wide limits—27 to 108 watts per bearing, according to Mr. Graves' tests—the motor must necessarily be selected to cover nearly the maximum safety. That means a rather large motor compared with the average useful plus friction load. Not only is there thus an unnecessary increase of first cost of the motor but, more seriously, the operating cost is unduly enhanced, as it is well known that a motor operating much below its rated capacity has low efficiency and is wasteful of current. When, on the other hand, the line shaft is mounted on ball bearings, the friction load is greatly reduced, its amount is more definitely determinable beforehand, and the initially smaller motor is used nearer at its point of maximum efficiency.

9. Mr. Jackson refers to a possible increase in shaft speed due to mounting the shaft on ball bearings, resulting in decreased weight of shaft pulleys and belts and more favorable belt contacts. All of these elements in time make for decreased bearing loads and consequently still further increases in economy. Mr. Jackson has had under his continual observation during several years a number of plain and ball-bearing line shafts of medium and high speeds, and so speaks not merely from theoretical reasoning, but from actual practice and observation.

10. *Reduced Importance of Improper Belt or Rope Tension.* The great variations in belt tensions that may be brought about by weather and temperature conditions, moist and dry atmosphere, etc., have been referred to by Mr. Parish. Both leather and cotton belts, as well as fibre ropes, are subject to considerable variations from these conditions. Possibly fully as important a factor is the average millwright or mechanic. The properly stressed belt is the exception. Most belts are tightened almost to the breaking point. The work thus lost in friction in plain bearings is directly proportional to a coefficient of friction ranging from 3 to 10 per cent for those conditions; but with the low coefficient of friction of $\frac{1}{2}$ to $\frac{1}{4}$ per cent for ball bearings a relatively enormous over-stressing of the belt has but comparatively little influence in increasing the journal friction losses.

11. The ball bearing is a most important factor in belt economy, since the absence of the plain bearing friction load permits the use of slack belts and makes for greatly increased belt life. Mr. Fred. Tay-

lor showed the consequent economy most conclusively in his paper Notes on Belting, (Transactions, Vol. 15, p. 204).

12 *Relative Efficiency of Direct Motor Drive and Ball-bearing Line Shafts.* Mr. Parker refers to the large factor of inefficiency of motors and inquires concerning the possible improvement in line-shaft belt drives due to the use of ball-bearings. While in the early days of the introduction of direct-driven tools much was expected from the saving due to cuting out the line-shaft friction, it soon developed that the need for using motors equal to the maximum demand of a tool brought in greater power losses because of such motors working on an average at points of low efficiency.

13 Unless the direct application of the motor results in greater convenience of handling the machine to produce a greater output, the direct drive is not justified. In that case, the mounting of countershaft, loose pulleys and line shaft on ball bearings will result in very considerable power savings. The tests made for the author by Messrs. Dodge & Day on line shafts showed savings of 35 per cent under average conditions; extended to the countershaft and loose pulleys the savings will readily amount to more than half of the total power consumption.

14 In line with this general question Mr. Zimmerman asks whether it would be advantageous to lengthen a group-drive line shaft to 60 ft. to take a larger group involving a shaft length of 100 ft. Unquestionably that will be economical so long as other considerations than those of line shaft and line-shaft motor losses do not govern. As to the relative losses in countershaft and line shaft, it may be said in general that they will be fairly equal. It is true that the countershaft does not run as continuously as does the line shaft, but that simply involves a transfer of the loss from the countershaft hanger to the loose pulleys; only when the belt is actually thrown off does this loss cease; if the loose pulley diameter is decreased, as it should be to decrease the belt tension, the loss is lessened.

15 *Ball vs. Roller Bearing.* Mr. Graves makes inquiry concerning the relative values of ball and roller bearings and their coefficients of friction. The coefficient of friction for good ball bearings has already been given as close to $\frac{1}{2}$ per cent; for roller bearings the friction is about double, assuming always that the rollers are kept in alignment and that hard and true rollers rolling on true and hardened surfaces are used. The real advantage of the ball bearing is not the difference in friction, but its endurance and the consequent permanence of the power saving. As the correct ball bearing employs

only a single row of balls it has no length; that at once cuts out all disturbances, due to deflections of shafts or housings, that seriously affect rollers. The readiness with which the ball bearing is housed to retain its lubricant and to keep out injurious grit, as well as the small space occupied, are also advantages peculiar to it alone. The coefficients of friction cited have been determined by oft-repeated tests. They are referred to the shaft diameter so that the values are directly comparable with those of plain journals.

16 *Reasons for Ball Bearing Cost.* Mr. Parker wishes to know whether the apparently high cost of ball bearings is due to the high cost of manufacture or to large selling expense. Concerning the latter it may be said that the expense of selling ball bearings is not at all high; it is, in fact, lower than in many other lines of high-grade precision machine elements. The cost resides in the absolute necessity for precision, and the character of manufacture. Ball bearings can fitly be compared only with high-grade tools of high-grade steels. The material is a special alloy steel, relatively high in carbon, manganese, chrome and silicon; this is a combination that is very refractory under the cutting tool. After hardening, rough and finish grinding cannot be forced, as that spoils the integrity of the rolling surface. Accuracy of a high degree is essential; the unit of measurement is the ten-thousandth part of an inch. Interchangeability of a high order is not to be secured cheaply.

17 The data showing the saving in power consumption, not in percentage, but in actual consumption, that Mr. Parker asks for, are given in the body of the paper in the table in Par. 36, on lines marked "Plain Bearings measured Kw." and "Ball Bearings measured Kw."

18 *Ball Bearings on Railways.* This use of ball bearings is outside of the subject matter of the paper, but as inquiry has been made by both Mr. Ferris and Mr. Graves it may be noted that ball bearings of the same type are in regular use for main-line railways and electric railways, on the axles in the former and for both axles and motors in the latter. On the Prussian-Hessian State railways the first of these bearings are still in use, and as the result of somewhat over 400,000 kilometers' run (250,000 miles) under standard passenger coaches, show no evidences of wear.

19 In Europe, as well as in the United States, careful comparative measurements, extending over many weeks of 2-min. observations, have shown savings in electric railway power consumption of over ten per cent, with incidental decrease in motor temperature. For main-line and electric railway service the direct power saving is of less

importance than the ability to take advantage of coasting; this saving may frequently rise to 37 per cent. The chief economy lies not in power saving, but in saving of lubricant, attendance, cost of renewals and, in electric railway operation, the keeping of the equipment more in service, and less in the repair shop for renewing bearing linings and rewinding armatures that worn plain bearings have allowed to sag into the polepieces.

20 *Type of Bearing Under Discussion.* The author purposely confined the paper to a report of results of tests made for him

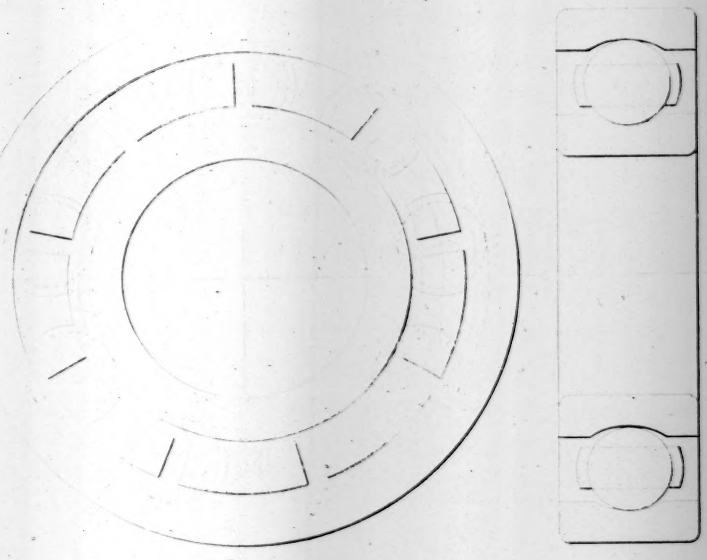


FIG. 1 ELEVATION AND CROSS SECTION OF THE HESS-BRIGHT BALL BEARING

by Messrs. Dodge & Day, preferring to bring out the engineering value and economic value to be expected of correctly made, correctly selected and properly mounted ball bearings. As Mr. Miller has asked for information concerning the specific ball bearing involved in the test it is proper to say that it is known in the United States as the Hess-Bright or DWF, and in Europe generally as the DWF.

21 Fig. 1 illustrates the ball bearing proper, in cross section and in elevation. It will be seen to consist of an inner race, an outer race, a series of balls, all of special steels hardened throughout, and a cage or

separator for the balls. The ball tracks have curvatures approximating the ball outline, the inner track very closely, the outer track slightly less so. The contact between balls and tracks is on a plane at right angles to the axis of the shaft, thus providing only one point of contact of the ball with each track. The sides of the races are continuous, with no interruption at any point for filling in the balls; that ensures absolutely smooth rolling of the balls and the absence of any possible contact with the edges of filling openings. In lieu of side interruptions or filling openings for the balls, assembly is by eccentric displacement of the two races, filling in balls through the wider space at one side, bringing the races into concentric relation, spreading the balls evenly and retaining them in proper position by the separator.

22 As to the refinement necessary in the making of these bearings, to which Mr. Miller kindly refers from his own observations, I would say that balls must be true to shape and to size within a limit of 0.0002 in. The bearing bore is held within a tolerance of 0.0002 in. +, and 0.0004 in. −. The outside diameter is held within 0.0006 in. +, and 0.0012 in. −, according to size. The width is held within 0.02 in. −. Each finished bearing is gaged for trueness of rotation with reference to the bore, and for trueness of the outer race on the ball circle. Each race is tested for uniformity of hardness, referred to a standard, at four points on each side, or eight per race; the sclerescope is used for this purpose, and that in turn is occasionally checked by the Brinnell, as well as the Turner and the Howe hardness test apparatus.

23 Lest it may appear that these refinements are not necessary, it may be well to say that the knowledge of their necessity has been acquired at great cost; also that only to the most painstaking care in material, treatment and workmanship is the success of the ball bearing due as an every-day reliable element of mechanism. A knowledge of proper proportions for various conditions of load, speed, shock, etc., is, of course, also essential.

THE BEST FORM OF LONGITUDINAL JOINT FOR BOILERS

By F. W. Dean, Published in The Journal for October 1909

ABSTRACT OF PAPER

This paper deals specially with the defects of the usual form of butt joint used on the longitudinal seams of boilers, in which the inside strap is wider than the outside strap. It gives some history of the joint and discusses some of its defects and suggests a substitution for this form.

While stating that there has never been an explosion of a horizontal return tubular boiler built with the ordinary form of butt joint, the author gives an example of the rupture of such a joint that would have resulted in an explosion. The joint recommended as a substitute for this, is one that has the inside and outside straps of the same width, but the outer row of rivets is made with a wide pitch and the straps are made sufficiently thick to stand caulking between the widely pitched rivets.

Ordinarily the efficiency of this substitute joint is from 84 to 85 per cent, but it can be made as great as that of any other form of joint, if the pitch of the rivets is wide enough, in which case the straps would have to be thicker than would otherwise be necessary.

DISCUSSION

Reginald P. Bolton. The form of longitudional joint for boilers, which Mr. Dean has described as the best, is as old as the time of Brunel, and was tested by him in 1838, and again by Longridge in 1857. It is a double-welt triple-riveted joint, omitting alternate rivets in the outer strip, and it has the defect of undue distance for calking between the outer rivets. It is not so good a joint as it would be when the triple riveting is continued, instead of omitting the alternate outer rivet. The other form of joint to which Mr. Dean refers, in which the inside welt was wider than the outside welt, has stood the test of many years usage, and I do not know of any case of failure.

2 In discussing the longitudinal joint, we should not lose sight of the fact that the weak parts of every longitudinal joint are the ends, where the two shell plates unite and the circular seams meet the longitudinal joint. It is there that weakness develops in all joint construc-

tion. In explosion cases on which I have been engaged, I have found that trouble has developed at those points, and have noted that ruptures commenced there. Therefore, in dealing with the design of longitudinal joints, the essential feature seems to me to be its character where it meets the circumferential seam.

E. D. MEIER. I think that the value of this joint depends largely on the diameter of the boiler that one has in mind. In a Scotch marine boiler, from 12 to 15 ft. in diameter, the joint would be an excellent one, especially with the scalloped edges mentioned by Mr. Dean. That is a very troublesome thing to do, but in addition to the advantage of the scalloped edge which Mr. Dean cited, there is the further one, that it modifies the tendency, common to such joints, to buckle at the point where the sheets come together. The butt joint is stiffer there than any other part of the shell and with a change in the pressure and temperature the buckling ultimately tends to impair the joint.

2 With a small boiler, 36 in., 42 in., or 48 in., in diameter, the joint is too large a proportion of the total circumference, and this action would become worse. That buckling action is distributed by making the butt plates as thin as possible, and making the inside one longer than the outside one.

3 The one joint that was not considered in the paper—the welded joint—will be an ideal one when we can be sure of a weld that will give 95 per cent efficiency. The difficulty will be to test it. We do know, however, that when we rivet a joint and do it honestly, we have something that can be relied on. Much will depend on how the material is chosen and how the work of laying up and riveting is done. The joint should be made by carefully bending the butt straps at a red heat to the true curve, and rolling the plate itself true to template. This will make as perfect a joint as possible. For a large diameter of boiler, I think the joint advocated by Mr. Dean, especially if the edges are scalloped, is an excellent one, but for smaller diameters I prefer the old joint.

4 Two other points must be considered: first, how the caulking is done, as in many sheets the initial fracture is caused by bad caulking; second, what sort of metal was used, for unless the chemical analysis of the plates as to minimum of injurious metalloids is firmly insisted on, trouble is sure to follow even in the best proportioned joints.

PROF. A. M. GREENE, JR. Mr. Dean is probably aware that in the 1893 report of the Chief of the Bureau of Steam Engineering of the

Navy, it is shown that the boilers intended for the New York, the Columbia and the Minneapolis, were all designed on the same plan as that which Mr. Dean recommends. The illustration in the paper is almost exactly similar to those in the report. These boilers were all installed and have given entire satisfaction.

2 Locomotive engineers, however, are using the unequal length butt strap quite extensively. I know of locomotives in which two rows of rivets were placed outside of the outer butt strap, and I do not know of any failure of such joints. If it is a case of getting increased efficiency, and still having the outer butt strap arranged for a caulking distance, I do not see why we should depart from the method of unequal straps to use the equal strap arrangement which cannot give such high efficiencies.

WILLIAM A. JONES. I wish to point out the tension which exists in the outer row of rivets and its effect on the drum shell. This should have an important part in determining whether the form of joint which Mr. Dean recommends is really better than if the outer butt strap were cut back one row of rivets on each side, so that the rivets at their caulking edges would be close together.

2 We probably all agree that rivets are more reliable in shear than they are in tension; that the closer and more firmly the edge of the outer butt strap is held down, the less caulking will be required and so the less possibility there will be of injuring the shell plates by caulking the butt strap in the shop, and the more remote will be the probability of subsequent leaks, prompting inexpert men to caulk them again later.

3 If we assume that the inner rivets are about 3 in. apart, then the outer rivets shown in the joint which Mr. Dean recommends will be about 6 in. apart, and each rivet will be holding an area of butt strap of from 15 to 20 sq. in., which, at 200 lb. pressure, will require from 3000 to 4000 lb. tension per rivet. In addition, each of these rivets will be required to hold the caulking for an edge about 6 in. long, and the caulking will have an advantage over the rivet of about 2 to 1, due to the leverage which it has because the rivets are back from the edge. It does not require much thought to see that these rivets would be better able to do this work if they were twice as close together.

4 The joint which Mr. Dean has shown has five rivets in double shear on each side, in a length equal to the pitch of the outer rivets, so that ten times the area of one rivet is the total area in shear in this length. If, on the other hand, the outer butt strap were cut back so

that the rivets at its edge would be close together and the outer rivets were in single shear, then the total area in shear would be only one-tenth less, and the proportion of the circular tension transmitted by the rivets in single shear could not be more than 11 per cent of the total in this case.

5 I understand that it is in an effort to improve the action of this 11 per cent of the force involved that this wide outer butt strap is recommended, and that where four rows of rivets are used instead of six, this proportion may rise to 20 per cent. In any case, the slight in the shell plate is less, I believe, than the bending tendency which the tension would produce in the rivets, due to pressure on the wide outer butt strap.

6 Let us consider the forces acting upon a rectangular area of plate in a drum shell under pressure. The circular tensions acting tangentially at the edges of this area are equal in intensity, but act at an angle to each other, so that each has a component normal to the chord of the area considered. These normal components exactly balance the pressure acting on that chord. When the area considered embraces a half-circle, the normal components become equal to the circular tension.

7 In the case of the outer butt strap, if all the circular tensions of the drum could be transmitted to the outer butt strap by rivets at its extreme edge, the shear of these rivets alone would hold the outer butt strap to the drum, and the components of the shears normal to the chord would just balance the steam pressure on that chord, so that no tension in the rivets would be necessary, except for caulking. Moving the rivets back from the edge of the butt strap makes the shear act more nearly parallel to the chord, while it does not diminish the chord, so that shear alone will no longer hold the butt strap in place, and tension must be developed in the rivets to make up the difference.

8 Transmitting part of the circular tension through the inside butt strap further increases the tension on the rivets, due to pressure, but the additional tension in this case maintains the curve in the inner butt strap by stitching it to the surface which receives the pressure and the reaction of the tension at the inner ends of these rivets is thus provided for.

9 In the case of the outer rivets of the joint which Mr. Dean shows, reaction of this tension at the inner ends of the rivets must be absorbed by an abrupt change in direction of the circular tension at those points, tending to produce corners in the drum shell in order to satisfy the triangle of the three forces formed by the tension on the rivet, the

tangential tension to the right, and the tangential tension to the left. If we assume a 42 in. drum, 200 lb. steam pressure, 6 in. pitch of outer rivets, each of which takes in tension the pressure of 20 sq. in., we have 4000 lb. tension in each rivet due to steam pressure, the inner ends of the rivets being anchored by an abrupt change in direction of about 9 deg. of 25,200 lb. circular tension.

10 Evidently, this abrupt change of direction of the total circular tension may readily distress the plate more in the form of joint which Mr. Dean recommends than in the usual form of joint with the narrow outer butt strap, even though a very small part of the circular tension is transmitted through a rivet in single shear.

11 Mr. Dean's statement that he believes there has been no case of failure of butt strap joints, would indicate that there was nothing wrong with the established form using the narrow outer butt strap. Certainly the remedy proposed seems more objectionable than a rivet in single shear.

SHERWOOD F. JETER.[1] It seems that all engineers design joints with reference to their weakest point, that is, provided the joint was to be ruptured in a machine. Of all explosions that to my knowledge have been due to ruptures, none of them have occurred in the theoretically weakest part of the joint. Most explosions due to rupture of the sheet have occurred near the joint and were apparently due to flexure of the metal, which had destroyed its life at the particular point of rupture.

2 I believe that there is a great need for an investigation as to what causes the rupture of the plate, and for other than machine tests of different kinds of joints. An account in Power states that there have been four ruptures of butt-strap joints of a nature similar to what was previously alluded to as a "lap cracking" of the joint. From the great number of lap joints in successful use for twenty-five years or more, it may be judged that something besides a mere lapping of the plates causes such defects.

THE AUTHOR. There is very little for me to say in closing, as my views have been fully set forth in the paper. I am interested in the history of this joint as stated by Mr. Bolton. I first knew of it in 1889; it is shown in Thomas W. Traill's book on boilers, and a table of sizes of parts is there given.

[1] The Bigelow Co., New Haven, Conn.

2 Several of the speakers express doubt as to the tightness of the joint on account of the wide spacing of the outer row of rivets. There should be no doubt of this kind, for too many of them are in use. I know of one joint with $1\frac{1}{4}$-in. rivets in 1-in. straps on a pitch of $9\frac{1}{8}$ in., and another with $1\frac{3}{16}$ in. rivets in a $\frac{7}{8}$-in. strap on a pitch of $8\frac{3}{8}$ in.

A REPORT ON CAST IRON TEST BARS

By A. F. Nagle, Published in The Journal for Mid-October 1909

ABSTRACT OF PAPER

This paper is designed to show engineers that test-pieces, whether cast in separate molds or in the same mold as the main casting, are not *perfect* indications of the character of the iron in the main casting. In other words, uniformity of results is not found in practice where we know of no reason why they should not be uniform. These test bars were used in the construction of over 3,000,000 lb. of pumping-engine castings, involving soft and hard irons for the various parts. Tables 5, 6 and 7 would indicate a probable variation of 15 per cent where uniformity might be expected.

DISCUSSION

Prof. W. B. Gregory. The writer has recently made a large number of tests of cast-iron specimens of one-inch square cross section and with supports 12 in. apart, a few being also broken in tension. The results confirm the deductions of the author as to the relationship between breaking loads in tension and in cross bending. The ten-to-one ratio holds in these tests as in those given by the author. Table 1 gives the results of the cross-bending tests, the load being applied at the center.

TABLE 1 TESTS IN CROSS BENDING

Specimens 1 in. by 1 in., 12 in. between centers, load applied at Center.

Number	Breaking Load Lb. per Sq. In.	Deflection In.
1	22[illegible]	0.10
2	2250	0.10
3	2680	0.09
4	2410	0.09
5	2250	0.08
6	2370	0.09
7	2240	0.09
8	2310	0.08
9	2250	0.09
10	2470	0.08
11	2180	0.10
Mean	2335	0.09

2 From the specimens broken in cross bending, six were selected from which were turned tension test pieces approximately $\frac{1}{2}$ in. in diameter at the smallest section, their length over all being 5 in. The threads at the ends were $\frac{3}{4}$ in. outside diameter. The test pieces were made to fit loosely into the tension bars of the testing machine so that side stresses were entirely eliminated, and the specimens were broken in pure tension. The results are given in Table 2.

TABLE 2 TENSION TESTS

Number	Breaking Load Lb. per Sq. In.
1	22900
2	23300
3	22800
4	23550
5	24600
6	22050
Mean	23200

The ratio of tensile strength to load in cross bending is

$$\frac{23200}{2335} = 9.94$$

This comparison can be made only on the basis of averages, as no record was kept of the numbers of the specimens broken in cross bending. The six tension specimens therefore represent six of the eleven specimens broken in cross bending. Specimen No. 9 of the cross-bending tests may be taken as fairly typical of the others. A chemical analysis was made of this specimen with the following results:

Total carbon	4.04
Silicon	1.76
Phosphorus	0.562

3 The mean deflection as given by the author averaged 0.45 in. for two sets of specimens and 0.44 in. for another set. The highest value of deflection in any case was 0.50 in. Since the deflection varies as the cube of the length of specimens between supports, it follows that the deflection for specimens tested with supports 24 in. apart should be eight times the deflection for a length between supports of 12 in. On this basis the specimens tested by the writer should have

$$\frac{0.45}{8} = 0.056 \text{ in.}$$

deflection instead of 0.09 in. average as the tests showed. Can this discrepancy be explained by the difference in chemical composition or is it due to other causes?

4 This raises the question of what deflection ought to be specified for one-inch square specimens with 12 in. between supports. Some specifications have recently been brought to the attention of the writer in which the minimum deflection was placed at 0.15 in. Is this commercial cast iron or does it call for a special mixture, expensive and hard to obtain?

5 The author has mentioned that the "skin of the metal" was of no appreciable thickness. I would like to ask if he has ever tried the effect of rattling on specimens. The process of rattling will remove the sand and the skin of the metal. In this connection the results in Table 3 may be of interest.

TABLE 3 TESTS OF CAST IRON IN CROSS BENDING

SPECIMENS ROUND, 1 IN. IN DIAMETER, 12 IN. BETWEEN CENTERS. NOT RATTLED.

No.	Breaking Load Lb.	Deflection In	Remarks
1	2450	0.075	Cast in pairs on end
2	3010	0.08	" " " " "
3	2670	0.07	" " " " "
4	2580	0.14	" " " " "
5	2700	0.09	" " " " "
6	2580	0.14	" " " " "
7	2620	0.08	" " " " "
8	2430	0.075	Cast flat
9	3360	0.09	" "
10	2750	0.08	" "
11	2990	0.09	" "
12	3170	0.09	" "
13	2950	0.095	" "
14	2960	0.12	" "
15	3080	0.10	" "
16	2580	0.075	Cast on end
Mean	2805	0.093	

6 The tests given in Table 4 are on specimens of the same size as those in Table 3. The metal used was as nearly the same as the foundry could make it and the specimens were placed in a rattler and the sand and "skin" removed by abrasion. From these figures it will be seen that rattling has increased the strength, of the specimens, the increase being 3474 − 2805 = 666 which divided by 2805, gives 23.85 per cent. This phenomenon has, been noticed by other experimenters.

TABLE 4

No.	Breaking Load Pounds	Deflection Inches
1	3750	0.09
2	3330	0.095
3	3400	0.08
4	3520	0.09
5	3640	0.09
6	3640	0.10
7	2760	0.075
8	3670	0.095
9	3060	0.09
10	4020	0.10
11	3440	0.09
Mean	3474	0.0904

7 The statement that rattling increases the strength by about 25 per cent seems to be borne out by experiments. The increased strength is probably due to a removal of some of the internal stresses in the specimens and to the fact that the particles of iron, by the process of tumbling the bars together, are allowed to arrange themselves so that they are better able to resist stresses than they were before rattling.

8 Since the breaking load varies directly as the moment of inertia of the cross section of the specimen about the gravity axis, we have

Ig for the specimens $1\frac{1}{4}$ in. diameter $= \frac{1}{4}\ \pi r^4 = 0.7854 \times 0.625^4 = 0.12$

Ig for the specimens 1 in. square $= \frac{1}{12}\ bh^3 = \frac{1}{12} = 0.0833$

Then

$$\frac{0.1203}{0.0833} = 1.44$$

Making the comparison between the unrattled round specimens and the square ones, we have

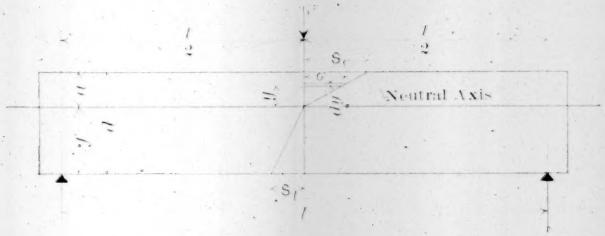
$$\frac{2805}{2335} = 1.2$$

Comparing the rattled round specimens with the square ones we have

$$\frac{3474}{2335} = 1.487.$$

GEO. M. PEEK. The paper brings up a point which I have had in mind for some time, and which I have never seen explained in any of the text books on the strength of materials or any of the engineer's

hand books. The formula in Par. 15 is obviously not applicable to cast-iron beams, for the reason that it assumes that the neutral axis of a rectangular beam is in the center, which is true only when the beam is made of a material with equal tensile and compressive strengths.



2 In order that we may be able to construct a formula to be used in the design of a beam made of material whose crushing and tensile strengths are not equal, we must know the ratio between them. It may be reduced as follows, referring to Fig. 1, herewith:

Let M = bending moment = $\frac{Pl}{4}$ for load at center of span.

P = load at center.
l = length between supports.
S_c = compressive strength.
S_t = tensile strength.
b = breadth of beam.
d = depth of beam.
a = distance to extreme fiber on compression side.
f = distance to extreme fiber on tension side.
K = ratio compressive strength to tensile strength.

All dimensions are in inches.

3 We have the moment of resistance on the compression side

$$\int_0^a b\sigma y\, dy = \int_0^a b S_c \frac{y^2}{a}\, dy = \frac{ba^2}{3} S_c$$

and in like manner we find the moment of resistance on the tension side to be $\frac{bf^2}{3} S_t$. Since these two resistances are on opposite sides of the neutral axis they must be equal, or

$$\frac{b\,a^2}{3} S_c = \frac{b\,f^2}{3} S_t \text{ or } \frac{a^2}{f^2} = \frac{S_t}{S_c} = \frac{1}{K} \therefore f = a\sqrt{K}$$

4 Since the sum of these two resistances must be equal to the bending moment we have

$$M = \frac{b a^2}{3} S_c + \frac{b f^2}{3} S_t$$

Substituting $K S_t$ or S_c

$$M = \frac{b S_t}{3} (K a^2 + f^2) = \frac{P l}{4}$$

$$P l = \frac{4}{3} b S_t (K a^2 + f^2) = \frac{8}{3} b S_t a^2 K$$

$$d = a + f = a (1 + \sqrt{K})$$

$$\therefore a^2 = \frac{d^2}{(1 + \sqrt{K})^2}$$

Substituting again

$$P l = \frac{8}{3} b d^2 \frac{K}{(1 + \sqrt{K})^2} S_t$$

$$S_t = \frac{3}{8} \frac{(1 + \sqrt{K})^2}{K} \frac{P l}{b d^2}$$

If we substitute 1.747 for K we get $S_t = \frac{P l}{1.155 b d^2}$ or Clark's formula.

5 Taking the average compressive strength of cast iron as 112,000 lb. per sq. in., and the average tensile strength as 28,000, or $K = 4$, we have

$$S_t = \frac{P l}{1.185 b d^2}$$

6 Applying this formula as Mr. Nagle does Clark's, in Par. 15, we have

$$\frac{2372 \times 1.185 \times 2 \times 1 \times 1}{24} = 2350$$

As will be seen, this formula gives results within 1.4 per cent of those obtained from the test.

A. A. Cary. It is unfortunate that the value of the structural study of metals and alloys, by use of the pyrometer and microscope, is

not more widely appreciated. I feel safe in saying that by such means all variations such as noted in Mr. Nagle's paper can be most satisfactorily accounted for. In iron and steel the fact is now generally recognized that metals identical in chemical composition may possess widely differing mechanical properties which are quickly recognized by microscopic examination.

2 Chemical analyses, as given in Table 1 of the paper, are undoubtedly of considerable value in the investigation of cast-iron; but without a physical examination our knowledge of the ability of the metal to withstand stresses and strains is very uncertain. Not only will investigations of this kind show us the cause of the variations noted in Mr. Nagle's paper, but they will give us the information needed to produce a metal of great uniformity.

PROF. T. M. PHETTEPLACE. It would be interesting to know whether a thorough sand-blasting would have any effect, as different results seemed to be obtained by cleaning off the skin of the material

THE AUTHOR. Since the paper was written I have had opportunity to examine some instructive records of eleven sets (of three each) of round test bars. The bars were $1\frac{1}{4}$ in. in diameter, rough, on 12-in. supports, the breaking loads being corrected for actual diameters. The deflections were not corrected.

BREAKING LOADS IN POUNDS. DEFLECTION FROM 0.12 IN. TO 0.15 IN.

1.....	3276	3185	3044	4400	4005	2913	3276	3306	3382	3204	3268
2.....	3367	3276	3162	3100	3913	3003	3185	3204	2976	3204	3124
3.....	3276	3534	3255	3500	3640	3115	3026	2937	3003	2912	2812

2 The three bars in each set were cast in three separate molds, No. 1, or the upper line, being cast from the first pour of the ladle, No. 2 from the middle and No. 3 from the bottom. It will be observed that in eight of these eleven sets, the bar selected from the two nearest in agreement, came from the middle of the pour, and that all of the extreme variations were found in either the first or last pour. If we have only two bars they would differ as much as 22 per cent, while if we took the two out of three nearest in agreement, those two would not vary more than 2 per cent or 3 per cent.

3 I am very glad that Mr. Peek has taken up the mathematical solution of fitting a formula to the facts. Whether his demonstration or Clark's is the correct, or the better, one, I will not attempt to say,

but it is a pleasure to find that the two methods agree so well with the facts. I trust that this publicity will banish the old form of formula from the text books.

4 Professor Gregory has made an oversight in the dimensions of my bars. Being twice as wide as his, the deflections do not show very great variations; as $4 \times 0.09 = 0.36$ to 0.45, instead of $8 \times 0.09 = 0.72$ to 0.45.

5 I have had no experience with bars 1 in. by 1 in. by 12 in., but I think that 0.15 in. deflection would be difficult to realize in machinery castings.

THE BUCYRUS LOCOMOTIVE PILE DRIVER

By Walter Ferris, Published in The Journal for November 1909

ABSTRACT OF PAPER

This paper describes a new railway pile driver recently put on the market. The leading feature is a very powerful propelling apparatus and a large boiler, enabling it to act as a locomotive and haul its own train of tool cars, boarding cars, etc., over the road.

In order to transmit more than 250 h.p. to the axles of ordinary bogie trucks, which do not remain in line with the car body when passing curves, a special type of driving connection has been developed and is described in detail with drawings. The machine carries the pile driver apparatus at one end or the car, with power devices for raising the leaders and for swinging them to either side of the track as desired.

To enable the machine to drive piles at the other end when no railway turntable is at hand, a special turntable is attached to the under-side of the main car sills just above the track. This consists of hydraulic lifting apparatus and a large ball bearing upon which the entire pile driver, including trucks, is lifted clear of the track and turned end for end in from ten to fifteen minutes.

DISCUSSION

A. F. Robinson.[1] I feel very much pleased with the behavior of this driver as far as we have gone. I am especially pleased with the last three drivers, which are equipped with the extra high-speed gear. Our men find in handling this driver that it saves a good deal of time over the locomotive, especially in the short moves required in spotting the pile for driving and also the short run back to the end of a bridge to obtain piles.

2 As soon as this machine is thoroughly understood a great many will be used. This will be especially the case when we use reinforced-concrete piling more extensively.

L. J. Hotchkiss.[2] There are in use many antiquated pile drivers which are slow and difficult to handle. In some cases the leaders

[1] Bridge Engineer, Atchison, Topeka and Santa Fé Ry.

[2] Asst. Bridge Engineer, Chicago, Burlington & Quincy R. R., Chicago, Ill.

must be raised by means of a set of blocks attached to the track ahead of the driver, the fall line being carried to a spool on the engine. With such a machine ten minutes may be required to raise or lower the leaders. Where the work is not too far from the station, and there are no overhead obstructions, it may not be necessary to lower the leaders when running to the station. In many places, however, the leaders must be lowered every time the pile driver goes in, and raised again on coming out. On a busy single-track railroad this may cause much loss of time in the course of the day.

2 The time loss may not be merely that directly caused by slow handling of the machine. In many locations the movement of trains is such that there are several periods during the day when with a quickly operated driver there is just time between trains to run out, drive one or two piles and get in the clear again. With a driver operated as previously described this cannot be done, as so much time is required to handle the leaders that there is none left for driving piles. There are, however, drivers which do not have this objection but which must be handled by a locomotive. This is expensive in two ways. There is charged to the work of pile driving the cost of engine service, and the locomotive is kept out of regular train service. In times of heavy business the latter item is in itself one of considerable importance.

3 The self-propelling feature of the machine described by Mr. Ferris, its large boiler capacity and the arrangement for turning it, are its most prominent features. As stated by Mr. Ferris, the usual charge for a locomotive and crew is from $20 to $30 per day, $25 being assumed as a fair average charge. The locomotive will furnish steam for the driver, making a fireman on the latter unnecessary. In the case of the self-propelling driver it is necessary to have a fireman, and as the machine is somewhat complicated, better men must be employed both as engineer and as fireman than would be needed ordinarily. For this reason the net saving by cutting out engine service probably will not exceed $20 per day. It is not unusual to have from 600 to 800 piles to drive on one division in a single season. If we estimate that 20 piles a day are driven, and this number is well above the average, 30 days will be required to drive 600 piles. For this period the charge for engine service would amount to $600, which is 5 per cent on an investment of $12,000. It will thus be seen that the elimination of engine service in pile-driving work is a matter of no small importance.

4 A machine such as Mr. Ferris describes has sufficient power and

steaming capacity to handle its own train a considerable distance. Where a long haul is to be made the propelling mechanism is quickly thrown out of gear and the whole outfit put in a regular train. One of these pile drivers recently handled a train consisting of four bunk cars, a locomotive tender fully loaded with coal and water, one car containing 40 tons of coal, and a way car. This train was taken up a 1.4 per cent grade more than a mile long. A few days later this driver hauled 140 tons in addition to its own weight up the same hill at about 7 miles per hour. The steam gage showed 175 lb. pressure when the top of the hill was reached.

5 The conditions of railroad operation today require that all possible economies be made both in operation and construction. The locomotive pile driver of large capacity is a recent development and one which must still be regarded, to a certain extent, as an experiment. Experience so far, however, indicates that it is an economical machine, in that it dispenses with locomotive service and is quickly handled on all classes of work.

THE AUTHOR. The railway pile driver is used for two general classes of work construction and maintenance. For construction work, in most cases, almost any track machine which is capable of driving piles will answer the purpose fairly well, because in such work the machine, if fairly well fixed, is able to stand for considerable periods of time at one place, and efficiency as a pile driver is the leading object.

2 In maintenance work, however, which generally consists in repairs, such as strengthening the abutment of a bridge which is showing some signs of washing down, or especially in repairs after a washout, the mobility of the machine is the leading feature. To illustrate this point, I may say that the first machine of this design which we built was tried out at a bridge in California which was a mile and a half from the nearest railroad siding. I happened to be with that machine at the time, and during the forenoon we ran it out from the siding to the bridge we were repairing, and back into the siding again, seven times, to dodge passing trains. During this time twelve piles were driven, one or two at each trip.

3 The base price of this machine is $11,650 without the turntable and the steam hammer. As the turntable and steam hammer, and electric light plant and other extras are added, the total price may run to something about $14,000. This represents an increase of cost to the railroad, above what they have been accustomed to pay

for a pile driver, of $3,000 to $4,000 for each machine. The experiment in the case of this machine was quite as much in the line of commercial engineering as of mechanical engineering. When we built the first machine we were a good many thousand dollars behind, and somewhat doubtful if we would get it back. It looks now as if the machine would take very well. The operating department of the Southern Pacific, to which we recently furnished a machine, had previously charged the bridge department $45 a day for the use of a locomotive, which was dispensed with by the use of a machine capable of doing its own propelling work.

THE PITOT TUBE AS A STEAM METER

By George F. Gebhardt, Published in The Journal for Mid-November 1909

ABSTRACT OF PAPER

The application of a pitot tube system along the lines described in the paper is an accurate means of determining the *velocity* of steam at any point in a pipe, provided the values of the various influencing factors are known; and for straight lengths of piping with continuous flow, under these conditions, it is an accurate means of determining the *weight* of steam flowing.

Under average commercial conditions in which the pressure and quality of the steam fluctuate and an average value must be taken for the density of the self-adjusting water column, only approximate results can be obtained, the extent of error varying with the degree of fluctuation.

For velocities in excess of those corresponding to a 1½-in. water column (about 2000 ft. per min. for pressures over 70-lb. gage pressure) tests gave a maximum error of about 2 per cent for continuous flow in straight lengths of piping.

The coefficient of the tubes, as applied in Fig. 12, is practically unity and no calibration of the apparatus is necessary.

Further tests are necessary to show whether application, as in Fig. 13 and Fig. 14, gives reliable results.

DISCUSSION

Prof. W. B. Gregory. The pitot tube was invented in 1730. An account of the tube and the manner in which it was invented may be found in Histoire de l'Academie des Sciences for 1732. This paper by Pitot is of considerable interest. Some of its accompanying drawings are reproduced in a paper which I presented before the Society on The Pitot Tube, published in the Transactions, Vol. XXV. The statement of Mr. Gebhardt that the tube was first used in 1837 is evidently a misprint.

2 The author has apparently developed a practical instrument of real value. However, it seems to the writer that the device for determining aspiration effects can not be relied upon to make determinations of any value. Fig. 6 shows a special fitting, which, after pipes are screwed into the two ends, will be anything but an ideal fitting to

give correct static pressures. Most of the trouble in the past has been on the static side. The fitting shown amounts to an enlargement of the pipe beyond the end of the entering pipe and then a contraction where the steam enters the outgoing pipe. Serious eddying must result and it does not seem at all likely that the slots *ss* are long enough to neutralize the effect of the eddying and the change of section. Even if they do correct these errors it does not follow that *B* is located where it will give the correct mean pressure in the special fitting. The change of section and consequent eddying may change the pressure along the special fitting so that the pressure shown at *B* is not the true mean pressure.

3 I would like to ask Professor Gebhardt if he has used static openings about 1/16 in. in diameter drilled at right angles to the axis of the pipe? Extensive experience with the pitot tube as a device for measuring the velocity of water has taught me to avoid irregularities in a pipe, due to special fittings or other causes, when the static pressure is taken from the walls of the pipe. An unobstructed length of straight pipe is absolutely essential to accurate work.

4 The desirability of finding the correct static pressure is apparent as it seems probable that one constant would apply to reduce velocity at the center to mean velocity, in any and all sizes of pipe. The experimental determination of the correct angles for the static nozzle, as shown in Fig. 5, would then be avoided.

WALTER FERRIS. The remarks of Professor Gregory in regard to the special fitting for finding the effect of aspiration reminded me forcibly of an experience a few years ago with both a venturi meter and a pitot tube for measuring water. Perhaps the conclusions at which I arrived at that time may be suggestive, although possibly not of direct application in the case of a steam meter.

2 Until quite recently, that is, within a few years, I think it has been assumed that it was necessary, in the use of the pitot tube, to have a static tube close to the dynamic tube, or at least at the same distance from the walls of the conduit. I believe that William Monroe White, six or seven years ago, made some experiments demonstrating that the velocity head taken from the impact side of a pitot tube is correct, whatever the shape of the nozzle, so long as it is a surface of revolution. Thus the nozzle may be either cylindrical, or a converging or diverging cone, and the dynamic head will be correctly indicated, any variations in the coefficient of the pitot instrument as a whole being due to the shape or location of the static opening.

3 In the venturi meter, we find that the static pressure is always taken from the walls of the conduit, where the velocity may not be over half the maximum velocity, and yet the results from the venturi meter are invariably correct to within one per cent, if conditions are favorable. Therefore a dynamic nozzle, which is a surface of revolution, combined with a static nozzle terminating in the wall of the conduit (as in the venturi meter) should together form a pitot instrument which is correct to the formula, and needs no calibration. This seems to indicate that for a pitot instrument to measure the flow of water it is not necessary to take the static head and the dynamic head in regions of the same velocity, and that the true average static pressure will be indicated through intervening velocities, and correctly registered, even when the piezometer is located in a region of low velocity. From this I infer that in this steam meter sufficiently small static openings in the true smooth wall will probably give correct results as they do in the water meter, although I have no experimental data with which to confirm this opinion.

A. R. Dodge. I would like to take exception to a statement in Par. 6: "On account of the great density of mercury and the variation in height of the condensed vapor above the mercury, this application of the pitot tube has very little value scientifically or commercially." The General Electric Company has developed a steam meter, both of the indicating and recording types and has built several hundred of these meters using mercury and condensed vapor above the mercury. This condensed vapor automatically remains at a constant head.

2 Recently three recording meters, selected at random out of a lot of fifty, showed a maximum error of less than two per cent. Ninety per cent of the readings were within one per cent on the three meters, which had an automatic pressure correction and also a temperature correction. These meters can be used on any size of pipe, from 2 in. up to 36 in., the 36-in. pipe, of course, being for atmospheric conditions of steam. These steam meters we have found to be valuable in improving the consumption of steam in our various plants.

3 We have also experimented with several of the types described in this paper in which mercury is not used and have found them excellent in many respects, but the use of mercury is not at all objectionable.

The Author. Prof. W. B. Gregory is correct in his statement concerning the defects in the apparatus for determining aspiration

as illustrated in Fig. 6. This drawing refers to an old discarded fitting and was published through an oversight. The apparatus used in connection with the tests recorded in the paper is the same in principle but differs in the details of construction. The inner surface of the fitting is of the same degree of smoothness as that of the pipe. This inner diameter of the chamber corresponds to that of the pipe. The ends of the pipes are threaded and finished in such a way as to fit snugly against the threaded end of the fitting, forming a practically continuous tube of uniform diameter. The slots are 10 in. long and $\frac{1}{4}$ in. in thickness. Careful measurements with searching tubes and delicately balanced differential manometer failed to show eddies of appreciable magnitude.

2 Static openings, about one-sixteenth of an inch in diameter, drilled at right angles to the axis of the pipe, showed no aspiration effects at velocities up to 15,000 ft. per min. (the maximum obtained during the tests) but are unsuitable for the appliances described. It is the author's intention to develop a simple meter which can be constructed of standard fittings and which may be attached by tapping the pipe in the ordinary way. Such an application necessitates the projection of the static nozzle beyond the inner surface of the pipe, an arrangement which causes serious aspiration. With a standard $\frac{1}{2}$-in. nipple projecting $\frac{1}{2}$-in. beyond the inner surface of a 3-in. pipe an aspiration effect corresponding to 10 in. of water was noted at a velocity of 12,000 ft. min. (pressure 100 lb. gage). At a velocity of 6000 ft. per min. the aspiration amounted to $1\frac{1}{2}$-in. of water. It was for the purpose of neutralizing this aspiration that the static nozzle was cut at an angle, as indicated in Fig. 5.

3 Mr. Ferris' remarks are in accordance with experiments conducted by the author, but, as stated above, a static opening terminating with the inner wall of the conduit is not applicable to the instruments in question. Fig. 1 illustrates such a static opening, but in the actual construction the nozzle projected $\frac{1}{2}$ in. beyond the inner surface.

4 Mr. Dodge's experiments with the use of mercury as an indicating medium are of considerable interest, in that they show the development of a practicable and accurate steam meter which is little known to the general engineering public. It would be of great interest if Mr. Dodge would describe the instrument used at the works of the General Electric Company and give some of the test results.

GENERAL NOTES

AMERICAN SOCIETY OF CIVIL ENGINEERS

At the meeting of the American Society of Civil Engineers, February 2, two papers were presented for discussion: Underpinning the Cambridge Building, New York City, by T. Kennard Thomson, Mem.Am.Soc.M.E., and Building Agreements, by Wm. B. Bamford. The papers presented at the meeting of February 16 were: The Effect of Alkali on Concrete, by Geo. Gray Anderson; and Precarious Expedients in Engineering Practice, by John Hawkesworth. On March 2, a paper entitled The Improved Water and Sewage Works of Columbus, Ohio, will be presented by John H. Gregory.

AMERICAN INSTITUTE OF MINING ENGINEERS

The Society takes pleasure in announcing the invitation extended to the members of this Society by the American Institute of Mining Engineers, to attend their Convention at Pittsburg, Pa., beginning Tuesday evening, March 1, 1910. The members of this Society will be welcome at the professional sessions and at such of the excursions as may be undertaken, where the number does not exceed the available facilities.

The Institute headquarters will be at the Hotel Schenley, where a bureau of information will be maintained, and the sessions will be held at the Carnegie Library, opposite the hotel. The Secretary of the Local Committee is Harrison W. Craver, Carnegie Library, Pittsburg, to whom should be addressed all inquiries concerning local matters and arrangements of the meetings.

There will be an excursion to the steel plant at Homestead, which will occupy one day, and an afternoon will be devoted to a visit to the testing station of the United States Geological Survey, where special tests will be made showing the effect of various explosives on mine gas, etc., also some tests on reinforced concrete beams. Arrangements will also be made for a visit to a coal mine and to various manu-

facturing plants. Details of the sessions and excursions will be given in the program furnished to each guest on registration at the headquarters.

THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS

The Society of Naval Architects and Marine Engineers is arranging for representatives to attend the fiftieth anniversary of the founding of the Institution of Naval Architects, to be held in London, July 5, 1910, and to be made the occasion of an international congress.

Papers and subjects connected with naval architecture and marine engineering will be read and discussed and the attendance of a large number of distinguished naval architects, shipbuilders and marine engineers from all parts of the world is anticipated.

INTERNATIONAL CONGRESS OF MINING, METALLURGY, APPLIED MECHANICS AND PRACTICAL GEOLOGY

An invitation to the International Congress of Mining, Metallurgy, Applied Mechanics and Practical Geology, to be convened at Dusseldorf, June 20–23, 1910, has been extended to the members of The American Society of Mechanical Engineers. This notice is published for the benefit of individual members who may be able to attend, as the Society is unable to accept as a body the invitation to be present.

NATIONAL CIVIC FEDERATION

The following Honorary Vice-Presidents were appointed to represent the Society at the conference of the National Civic Federation in Washington, D. C., January 17–19, 1910: Jesse M. Smith, Past-President, Chas. Kirchhoff, A. W. Burchard, E. G. Spilsbury, F. M. Whyte and Wm. H. Wiley.

The conference was called to consider uniform state legislation and has formed itself into a permanent organization for the purpose with Alton B. Parker as President. Annual conferences will probably be called. The conference endorsed the conservation of American forests and referred the matter of uniform state laws, providing for right methods of forests taxation and for the effective protection of forests from fire, to the Commission on Uniform State Laws. The regulation of water power by state and federal control was also recommended. A number of other resolutions were passed

upon subjects of national importance, urging uniformity in laws relating to taxation, insurance, child labor, public accounting, legal procedure, etc.

NEW YORK ELECTRICAL SOCIETY

On January 27, 1910, Prof. W. S. Franklin of Lehigh University gave a lecture before the New York Electrical Society, 29 West 39th Street, New York, on The Practical Applications of the Gyrostat. Professor Franklin discussed the physical action and the establishment of the kinematical diagram of the gyroscope, the gyrostatic action of the flywheel of the automobile engine and on shipboard, as well as of the boomerang, Schlick's device for the prevention of rolling of ships at sea, and the Brennan monorail car.

ENGINEERS CLUB OF PHILADELPHIA

The thirty-first annual meeting of the Engineers Club of Philadelphia was called to order by the President Dallett, February 5, 1910, with 129 members and visitors in attendance. An address on Recent Developments in Engineering Practice was made by President Dallett. Following a report of the tellers the following were declared elected as officers of the club: Wm. Easby, Jr., president; Chas. Hewitt, vice-president; W. Purves Taylor, secretary; E. J. Kerrick, treasurer.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

The regular monthly meeting of the American Institute of Electrical Engineers was held in the auditorium of the Engineering Societies Building, on Friday, February 11, 1910. W. Lee Campbell of the Automatic Electric Company of Chicago presented a paper entitled, A Modern Automatic Telephone Apparatus. A complete installation connected up for service was on exhibition.

At the annual dinner of the Institute, held at the Hotel Astor on Thursday evening, February 24, Dr. Elihu Thomson, to whom has been awarded the first Edison Medal, was the guest of honor. The following were the speakers of the evening: Dr. John H. Finley, president, College of the City of New York, Education and Invention; Samuel Insull, president Edison Medal Association, Meritorious Achievement in Electrical Engineering; Lewis Buckley Stillwell,

president, A.I.E.E., The Edison Medal, with response by Dr. Thomson. Mr. T. C. Martin acted as toastmaster.

WESTERN SOCIETY OF ENGINEERS

The Chanute medals of the Western Society of Engineers, founded by Dr. Octave Chanute, have been awarded for 1908 to Horace E. Horton, Prof. A. N. Talbot and Morgan Brooks, Mem.Am.Soc.M.E. Mr. Horton's paper was Compression Bridge Members, Professor Talbot's a report of Tests of Reinforced Concrete and Cast-Iron Pipe, and Professor Brooks' was Alternators in Parallel.

SHEFFIELD SCIENTIFIC SCHOOL NEW LABORATORY OF MECHANICAL ENGINEERING

A gift of $250,000 has recently been received by the Sheffield Scientific School of Yale University, from George G. and William S. Mason, graduates in the class of 1888, to be expended for the construction and equipment of a new mechanical engineering laboratory, on a site to be provided by the Board of Trustees. The laboratory will be located on Hillhouse Avenue, will be four stories in height, and will contain approximately 50,000 sq. ft. of floor area and 880,000 cu. ft. of space. The entire equipment will be new and will consist of the most modern appliances for assisting the student in studying the fundamental principles of applied science closely related to mechanical engineering, such as the strength of materials, the combustion of fuel in furnaces and in internal-combustion engines, the making of steam in boilers of different types, the using of saturated and superheated steam in engines or steam turbines, the artificial production of cold, the production, transmission and use of compressed air, the pumping of water, the transmission of power, and the problems of heating and ventilation. It is expected that this laboratory will furnish a field for research work in engineering science, as well as undergraduate and graduate instruction. It is expected that the building will be completed and equipped by June 1911.

COLUMBIA UNIVERSITY COURSE IN WORKS MANAGEMENT

A series of twenty lectures by non-resident lecturers is being conducted in the Department of Mechanical Engineering, Columbia

University, constituting a course in Works Management. Lectures are given on Thursdays and Mondays of each week, at 4.10 p.m., beginning February 10 and closing May 14, in Room 301 Engineering. The course consists, in the following order, of six lectures by Charles B. Going, managing editor of the Engineering Magazine; four by Charles U. Carpenter, Mem.Am.Soc.M.E., president of the Herring-Hall-Marvin Safe Company; two by H. L. Gantt, Mem.Am. Soc. M.E., one by Walter M. McFarland, Mem.Am.Soc.M.E., vice-president of the Westinghouse Electric & Mfg. Co.; three by Harrington Emerson, Mem.Am.Soc.M.E.; three by Richard T. Lingley, C.P.A., treasurer of the American Real Estate Company; and a concluding lecture by Edwin J. Prindle, member of the New York Bar.

STEVENS INSTITUTE ALUMNI DINNER

The ninth annual dinner of the Stevens Institute Alumni Association was held in the Hotel Astor on February 12. Among the speakers were Dr. Alex. C. Humphreys, Mem.Am.Soc.M.E., President of the Institute, Dr. H. S. Pritchett of the Carnegie Foundation, and Col. G. B. M. Harvey of Harper's Weekly.

PERSONAL

A. Bement has been elected second vice-president of the Western Society of Engineers. Mr. Bement presented a paper on the Chicago Harbor Problem before this Society at their meeting of February 16.

Morgan Brooks has been awarded one of the Chanute medals of the Western Society of Engineers for 1908. His paper was on Alternators in Parallel.

C. P. Chester, formerly superintendent of the Morenci Water Company, Morenci, Ariz., has opened a consulting engineering office in El Paso, Texas.

C. W. Comstock has been appointed president of the Comstock-Wellman Bronze Company, Cleveland, O.

Thomas F. Cooke has formed a partnership for consulting engineering with Richard L. Webb, under the name of Webb & Cooke, with an office in Buffalo, N. Y. The firm will make a specialty of power costs.

Fred H. Daniels has been decorated with the Cross of Knighthood of the Northern Star by King Gustav of Sweden in token of his work as an engineer and for courtesies extended to Swedish engineers in this country.

Arthur Falkenau, formerly president of the Falkenau-Sinclair Machine Company, Philadelphia, Pa., has become associated with George K. Hooper, New York.

J. Edwin Fulweiler has become associated with the United Gas Improvement Company of Philadelphia. He was until recently in the engineering department of the Otto Gas Works, Philadelphia, Pa.

W. B. Gregory has been elected president of the Louisiana Engineering Society.

Edwin J. Haddock, formerly chief engineer of the chain department of the Jeffrey Manufacturing Company, has given up his office in Columbus, O., to become mechanical and structural engineer of the Tennessee Coal, Iron & R. R. Co., in the coal mining department, with office at Birmingham, Ala.

F. A. Hall, manager of the chain block and hoist department of the Yale & Towne Mfg. Co., New York, has resigned that position to become vice-president and treasurer of the Cameron Engineering Company, of Brooklyn, N. Y.

F. A. Halsey sailed January 20 on the steamship Arabic for a cruise to the Mediterranean and the Orient. Mr. Halsey expects to be gone about three months and before returning intends to visit some of the important industrial centers of Europe.

Walter Laidlaw, formerly vice-president and general manager of the Snow Steam Pump Works, Buffalo, N. Y., has become identified with the International Steam Pump Company, New York.

Wm. Y. Lewis, formerly manager of the erecting department of the International Steam Pump Company, has established an office of his own at 49, Queen Victoria St., London, E. C., as advisory engineer.

W. A. McFarland, for many years superintendent of the Washington, D. C., water works, has opened an office in the Washington Loan and Trust building, as consulting engineer in matters relating to water works and power plants. He will be associated in a consulting capacity with the engineering firm of Beale & Meigs, which carries on a general engineering practice.

C. J. Morrison, until recently connected with the Emerson Company, has opened an office in New York for efficiency engineering work.

Leslie Moulthrop has received his discharge from the Superior Court as receiver of the Dwight Slate Machine Company, Hartford, Conn., having paid the general creditors in full. The company will be conducted under the same name by a new organization.

Albert Spies has retired from the editorship of the Electrical Record to become the managing director of Foundry News, a new illustrated monthly publication devoted to the foundry arts.

George F. Starbuck, formerly draftsman of the mechanical department of the N. Y., N. H. & H. R. R., New Haven, Conn., has become associated with the Boston Elevated Railway, Boston, Mass., as draftsman in the department of rolling stock and shops.

Cecil H. Taylor has been appointed chief engineer of the Hudson Motor Car Company, Detroit, Mich. He was formerly designing engineer of the Chalmers Motor Car Company, Detroit, Mich.

Charles E. Waddell, formerly consulting engineer, Biltmore Estate, Biltmore, N. C., has established offices for general engineering practice in Asheville, N. C.

Gilbert S. Walker, formerly located at Wheeling, W. Va., has become connected with the Isthmian Canal Commission, Washington, D. C.

James T. Wallis, superintendent of motive power on the Erie division of the Pennsylvania R. R. and the Northern Central has been appointed acting superintendent of the West Jersey & Seashore, R. R., also of the Philadelphia and Camden Ferry, with office at Camden, N. J.

C. H. Zehnder has been elected vice-president of the Empire Steel & Iron Co.

W. H. Zimmerman, formerly manager of the Michigan Power Company, Lansing, Mich., has been retained by the Michigan Railroad Commission as consulting engineer.

CURRENT BOOKS

ENGINEERS' AND FIREMEN'S LICENSE LAW; BOILER INSPECTION LAW; RULES FORMULATED BY THE BOARD OF BOILER RULES. Pamphlet issued by the Commonwealth of Massachusetts, 1909. *Wright & Potter Printing Co., Boston, Mass., 1909.* Viii + 67 pp., illustrated.

Contents: Engineers' and Firemen's License Law; Boiler Inspection Law; Rules formulated by the Board of Boiler Rules; Recommendations made by the Board of Boiler Rules; Index to Rules

FOWLER'S ELECTRICAL ENGINEER'S POCKET BOOK. Edited by Wm. H. Fowler. 10th annual edition. *Scientific Pub. Co., Manchester, England, 1910.* Cloth, pocket book size, 575 pp., illustrated. Price 1/6 net.

Contents: Miscellaneous Tables, etc.; Wire Tables; Magnetism and Magnetic Data; Conductors and Insulating Materials; Electric Lighting and Wiring; Comparison and Measurement of Resistances; Electrical Measuring Instruments; Electricity of Meters; Primary and Secondary Batteries; Dynamos and Motors; Alternate Electric Currents; Alternators; Transformers; Alternate Current Motors; Switch boards, Circuit Breakers and Lightning Arresters; Electrical Power Transmission and Distribution; Rotary Converters; Electric Traction; Rules and Regulations.

FOWLER'S MECHANICAL ENGINEER'S POCKET BOOK. Edited by Wm. H. Fowler. 12th annual edition: *Scientific Pub. Co., Manchester, England, 1910.* Cloth, pocket book size, 653 pp., illustrated. Price 1/6 net.

Contents: Miscellaneous Tables and Formulæ; Steam Boilers and Fittings; Fuels and Combustion Steam Engines; Steam Turbines; Locomotives; Steam Tables; Valves and Valve Gear; Gas Engines; Gases used in Gas Engines; Oil Engines; Hydraulics; Pumps and Pumping Arrangements; Gearing and Lubrication; Hoisting and Lifting Machinery; Mining Machinery and Appliances; Metallurgy of Iron and Steel; Strength of Metals and Alloys; Beams and Pillars; Springs; Chemistry; Ventilation and Heating.

SLIDE RULE. AN ELEMENTARY TREATISE. By J. J. Clark, M.E. *Technical Supply Co., New York, 1909.* Cloth, 6 vo., 62 pp., with diagrams. Price, 45 cents.

Contents: Introduction; the Mannheim Slide Rule.

SMOLEY'S TABLES. Parallel Tables of Logarithms and Squares, Angles and Logarithmic Functions, with complete set of Five-Decimal Logarithmic-Trigonometric Tables. By Constantine Smoley, C.E. 5th edition, revised. *Engineering News Pub. Co., New York, 1908.* Morocco, pocket book size. Price, $3.50.

Contents: Parallel Tables of Logs and Squares; Table of Bevels; Multiplication Table; Explanation and Examples; Constants; Decimal Equivalent; Logarithms of Numbers; Log. Functions by 10″; Angles Between 0° and 1° Log. Functions by 1′; Natural Functions; Formulæ; Constants; Decimal Equivalents.

TIME AND ITS MEASUREMENT. By James Arthur. Reprinted from Popular Mechanics Magazine, Chicago, 1909. Cloth, 12 vol., 64 pp., illustrated.

Contents: Historic Outline; Japanese Clocks; Modern Clocks; Astronomical Foundation of Time

FOWLER'S MECHANICS' AND MACHINISTS' POCKET BOOK AND DIARY, 1910. Edited by Wm. H. Fowler. 2d edition. *Scientific Pub. Co., Manchester, England, 1910.* Cloth, pocket-book size, 448 pp. Price 6d.

Contents: Handy References and Tables; Mensuration, Geometry, and Trigonometry; Uses of Logarithms and Antilogarithms; Materials Used in Machine Construction; Machine Tool Design; Proportions of Machine Tool Parts, Metal Cutting Tools; High Speed Tool Steels; Drilling and Boring Metal; Screw Threads, Screw Cutting, and Taper Turning; Emery and Emery Wheels; Shop Practice; Wheel Gearing; Belt and Rope Driving, Shafting; Lifting Ropes and Chains.

KEMPTHORNE'S RAILWAY STORES PRICE BOOK. Being a Handbook of Prices of Stores and Material used in the Construction and Maintenance of Railways. By William Oke Kempthorne. *E.&F.N. Spon, Ltd., London, England, 1909.* Cloth, 8 vo., 487 pp. Price, $4.

THE CIVIL ENGINEER'S POCKET BOOK. By John C. Trautwine. 19th edition. *New York, John Wiley & Sons, 1909.* Morocco, pocket-book size, pp. xxxii + 1257 + 26. Price, $5.

Contents: Mathematics; Natural Phenomena; Mechanics, Force in Rigid Bodies; Strength of Materials; Hydrostatic Hydraulics; Constructions, etc.; Water Supply; Traction, Animal Power; Suspension Bridges; Rivets and Riveting; Railroads; Materials; Price List, etc.; Bibliography; Logarithmic Sines, etc.; Concrete.

LARGE GAS ENGINES. By Percy R. Allen. Reprinted from Cassier's Magazine, 1909. Cloth, 61 pp.

Contents: The Four-Cycle Engine—British and Continental Practice; The Four-Cycle Engine—American Practice; Two-Cycle Engines.

ENERGY. Work, Heat and Transformations. By Sidney A. Reeve, M.E. *New York, McGraw-Hill Publishing Co., 1909.* Cloth, 8 vo., 238 pp. Price, $2.

Contents: Mechanical Energy; Free and Vibratory Energies; The Mean Energetic Condition and the Energy-fund; The Two Factors of Dimensions of Energy; The Extreme or Critical Energetic Conditions; The General Nature of Mechanical Energy; What is Heat?; The Thermal Diagram; Mechanical Concepts of Thermal Phenomena, Pressure and Volume; The Two Basic Thermal Processes: Heat-transfer and Work-performance; Mechanical Concepts of Thermal Phenomena, Temperature and Entropy; The Energetic Cycle; Reversed and Irregular Cycles; Thermal Equilibrium; Transformations and Conservations.

LINSEED OIL AND OTHER SEED OILS. An Industrial Manual. By Wm. D. Ennis, M.E. *New York, D. Van Nostrand Co., 1909.* Cloth, 8 vo., xiv + 316 pp. Price, $4.

Contents: Introductory; The Handling of Seed and the Disposition of Its Impurities; Grinding; Tempering the Ground Seed and Molding the Press Cake; Pressing and Trimming the Cakes; Hydraulic Operative Equipment; The Treatment of the Oil from the Press to the Consumer; Preparation of the Cake for the Market; Oil Yield and Output; Shrinkage in Production; Cost of Production; Operation and Equipment of Typical Mills; Other Methods of Manufacturers; The Seed Crop; The Seed Trade; Chemical Characteristics of Linseed Oil; Boiled Oil; Refined and Special Oils; The Linseed Oil Market; The Feeding of Oil Cake; Miscellaneous Seed Oils; The Cotton-Seed Industry.

HENLEY'S ENCYCLOPEDIA OF PRACTICAL ENGINEERING AND ALLIED TRADES. A Practical and Indispensable Work of Reference for the Mechanical Engineer, Designer, Draftsman, Shop Superintendent, Foreman and Machinist. Edited by Joseph G. Horner, A.M.I.Mech.E. *New York, The Norman W. Henley Pub. Co., 1909.* Vol. IX, SPE-Z, 240 pp., Illustrated. Price, $6.

THE GAS ENGINE. By Cecil P. Poole. *Hill Pub. Co., New York, 1909.* Cloth, 8 vo., 6 + 97 pp., illustrated. Price, $1.

Contents: Elementary Principles; Pressures and Temperatures; Cooling and Heat Loss; Valves and Valve Gear; Ignition; Mixing Liquid Fuel with Air; Methods of Governing; Some Considerations of Design; Care and Management of Engines; Pressure, Temperature and Output Calculations.

ACCESSIONS TO THE LIBRARY

This list includes only accessions to the library of this Society, included in the Engineering Library. Lists of accessions to the libraries of the A.I.E.E. and A.I.M. E. can be secured on request from Calvin W. Rice, Secretary, Am.Soc.M.E.

American Mining Congress. Report of Proceedings. Vol. 12. 1909. *Denver 1909.*

American Railway Association. Statistical Bulletin Nos. 60, 63, 63A. *Chicago, 1910.*

Arrangement of Engine Cylinders to Produce Uniform Torque. Reprinted from Electrical World, November 11, 1909.

Association of Transportation and Car Accounting Officers. *Proceedings.* December 1909. *Chattanooga, 1909.*

Bibliography of North American Geology for 1908, with subject index. (Bulletin 409, U. S. Geol. Survey.) By J. M. Nickles. *Washington, 1909.*

Boston, Finance Commission. Report. Vol. 4. *Boston, 1909.* Gift of Samuel Whinery.

Commercial Deductions from Comparisons of Gasoline and Alcohol Tests on Internal-Combustion Engines. (Bulletin 392, U. S. Geol. Survey.) By R. M. Strong. *Washington, 1909.*

Commission de l'Unification Internationale des Pas de Vis dans les Appareils d'Utilisation du Gaz. Second session, June, 1909.

Comparative Tests of Run-of-Mine and Briquetted Coal on the Torpedo Boat Biddle. (Bulletin 403, U. S. Geol. Survey.) By W. T. Ray and H. Kreisinger. *Washington, 1909.*

Connecticut Bureau of Labor Statistics. 23d report. *Hartford, 1908.* Gift of the Bureau.

Cornell University. Librarian's Report. 1908-1909. *Ithaca.*

Cost Keeping and Management Engineering. By H. P. Gillette and R. T. Dana. *New York-Chicago. Myron C. Clark Pub. Co., 1909.*

Devonian Fauna of the Ouray Limestone. (Bulletin 391, U. S. Geol. Survey.) By E. M. Kindle. *Washington, 1909.*

Electrical Engineer's Pocket Book, 1910. ed. 10. By W. H. Fowler. *Manchester, Scientific Pub. Co., 1910.*

Engineers' Club of Cincinnati. Annual Address, December 16, 1909. By F. M. Crocker. *Cincinnati, 1909.*

Equitable Charges for Tramway Supply. By H. E. Yerbury. (Institution of Electrical Engineers, 1909.) Gift of C. W. Rice.

Geological Features of the Country Lying along the Route of the Proposed Transcontinental Railway in Western Australia. (Bulletin 37, Western Australia Geol. Survey.) By C. G. Gibson. *Perth, 1909.*

GEOLOGY AND UNDERGROUND WATERS OF SOUTH DAKOTA. (Water Supply Paper No. 227, U. S. Geol. Survey.) By N. H. Darton. *Washington, 1909.*

GEOLOGY AND WATER RESOURCES OF THE NORTHERN PORTION OF THE BLACK HILLS AND ADJOINING REGIONS IN SOUTH DAKOTA AND WYOMING. (Professional Paper No. 65, U. S. Geol. Survey.) By N. H. Darton. *Washington, 1909.*

GEOLOGY OF THE LEWISTOWN COAL FIELD, MONTANA. (Bulletin 390, U. S. Geol. Survey.) By W. R. Calvert. *Washington, 1909.*

GRANITES OF VERMONT. (Bulletin 404, U. S. Geol. Survey.) By T. N. Dale. *Washington, 1909.*

HOW TO MAKE IMPROVEMENT THINNINGS IN MASSACHUSETTS WOODLANDS. By H. O. Cook. *Boston, 1910.* Gift of Massachusetts State Forester.

INCIDENTAL PROBLEMS IN GAS-PRODUCER TESTS. (Bulletin 393, U. S. Geol. Survey.) By R. H. Fernald and others. *Washington, 1909.*

LANDSLIDES IN THE SAN JUAN MOUNTAINS, COLORADO. (Professional Paper No. 67, U. S. Geol. Survey.) By E. Howe. *Washington, 1909.*

MACHINE BUILDING FOR PROFIT AND THE HARTNESS FLAT TURRET LATHE. By James Hartness. *Springfield, Vt., 1909.*

MAGNETIC SURVEY YACHT CARNEGIE AND HER WORK. From Terrestrial Magnetism, June 1909.

MANZANO GROUP OF THE RIO GRANDE VALLEY, NEW MEXICO. (Bulletin 389, U. S. Geol. Survey.) By W. T. Lee and G. H. Girty. *Washington, 1909.*

MECHANICAL ENGINEER'S POCKET BOOK. ed. 12. By W. H. Fowler. *Manchester, Scientific Pub. Co., 1910*

MECHANICS' AND MACHINISTS' POCKET BOOK AND DIARY, 1910. By W. H. Fowler. *Manchester, Scientific Pub. Company.*

MERCURY MINERALS FROM TERLINGUA, TEXAS. (Bulletin 405, U. S. Geol. Survey.) *Washington, 1909.*

METALLOGRAPHIE. By W. Guertler. Pt. 2. *Berlin, G. Borntraeger, 1909.*

NATIONAL ELECTRIC LIGHT ASSOCIATION. (Bulletin, Vol. 3, No. 6.) *New York, 1910.* Gift of C. W. Rice.

NEW YORK CHAMBER OF COMMERCE. 51st Annual Report of the Corporation. *New York, 1909.* Gift of N. Y. State Chamber of Commerce.

NEW YORK STATE FOREST, FISH AND GAME COMMISSION. 14th and 15th Annual Reports. *Albany, 1909, 1910.* Gift of Commissioner.

NEW YORK STATE MUSEUM. 62d Annual Report. Vol. 2-4. *Albany, 1909.*

NON-MAGNETIC GAS ENGINE OF THE CARNEGIE. By J. Craig, Jr. From Terrestrial Magnetism, September, 1909.

NOTES ON SOME MINING DISTRICTS IN HUMBOLDT COUNTY, NEVADA. (Bulletin 414, U. S. Geol. Survey.) By F. L. Ransome. *Washington, 1909.*

OHIO ENGINEERING SOCIETY. Proceedings of 13th Annual Meeting. *Columbus, 1909.*

OKLAHOMA STATE UNIVERSITY. Research Bulletin. Nos. 1-2. *Norman, 1909.*

PASSENGER CAR LIGHTING. By Representatives of different Car Lighting Systems. Gift of Canadian Railroad Club.

PLEISTOCENE GEOLOGY OF THE LEADVILLE QUADRANGLE, COLORADO. (Bulletin 386, U. S. Geol. Survey.) By S. R. Capps, Jr. *Washington, 1909.*

PRIMER ON EXPLOSIVES FOR COAL MINERS. (Bulletin 423, U. S. Geol. Survey.) By C. E. Munroe and C. Hall. *Washington, 1909.*

Radioactivity of the Thermal Waters of Yellowstone National Park. (Bulletin 395, U. S. Geol. Survey.) By H. Schlundt and R. B. Moore. *Washington, 1909.*

Railway Stores Price Book. By W. O. Kempthorne. *London-New York, Spon & Chamberlain, 1909.*

Results of Spirit Leveling in West Virginia. 1896-1908, inclusive. (Bulletin 399, U. S. Geol. Survey.) By S. S. Gannett and D. H. Baldwin. *Washington, 1909.*

Slide Rule. By J. J. Clark. *Scranton, 1909.* Gift of author.

Smoley's Tables of Logarithms and Squares. ed. 5. *New York, Engineering News Pub. Co., 1908.*

Study of the Massachusetts Wood-Using Industries. By Hu. Maxwell. *Boston, 1910.* Gift of Massachusetts State Forester.

Sydney University Engineering Society, New South Wales. *Proceedings.* Vol. 13, 1908. *Sydney, 1908.*

Tests of Run-of-Mine and Briquetted Coal in a Locomotive Boiler. (Bulletin 412, U. S. Geol. Survey.) By W. T. Ray and H. Kreisinger. *Washington, 1909.*

Time and its Measurement. By James Arthur. *Chicago, 1909.* Gift of Daniel Arthur.

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Utilization of Fuel in Locomotive Practice. (Bulletin 402, U. S. Geol. Survey.) By W. F. M. Goss. *Washington, 1909.*

Valuation of Public Service Corporations. By W. H. Williams. Gift of author.

Water Resources of the Blue Grass Region, Kentucky. (Water Supply Paper No. 233, U. S. Geol. Survey.) By G. C. Matson. *Washington, 1909.*

Fourteen Miscellaneous Books. Gift of Andrew Carnegie.

EXCHANGES

American Gas Institute. *Proceedings.* Vol. 4, 1909. *1910.*

Design of Surface Condensers. By R. M. Neilson. Institution of Engineers and Shipbuilders in Scotland.

Institution of Civil Engineers. Minutes of Proceedings. Vol. 178. *London, 1909.*

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New Charter Suggestions submitted to the Board of Freeholders by the Board of Public Improvements, 1909. Engineers' Club of St. Louis. *St. Louis, 1910.*

Synopsis of the Report of the Superintendent of the United States Naval Observatory. 1909. *Washington, 1910.*

Worcester Polytechnic Institute. Annual Catalogue, 1909-1910. *Worcester, 1909.*

TRADE CATALOGUES

American Spiral Pipe Works, *Chicago, Ill.* Spiral riveted pipe, forged steel pipe flanges, hydraulic and exhaust steam supplies, 20 pp.

JAMES BEGGS & CO., *New York.* Feed water filtration, 32 pp.

COMMERCIAL CABLE CO., *New York.* Silver anniversary souvenir, 36 pp.

CUMMINGS FILTER CO., *Philadelphia, Pa.* Water filters, 48 pp.

GENERAL ELECTRIC CO., *Schenectady, N. Y.* Bulletin 4679-A, Type DLC, commutating pole motors, 8 pp.; Bulletin 4684, Luminous arc headlight, 3 pp.; Bulletin 4706, Curve-drawing ammeter and voltmeter, 4 pp.; Bulletin 4707, Gasolene-Electric generating sets for lighting and power, 24 pp.; Bulletin 4708, Thomson direct current test meter, 4 pp.; Bulletin 4709, Portable instruments, 10 pp.; Bulletin 4713, Type F, forms K-2 and K-4 oil break switches, 7 pp.

GOLDSCHMIDT THERMIT CO., *New York.* Reactions, Vol. 2, No. 4, 20 pp.

HANDY INDEX CO., *New York.* Handy Index for January 1910, 64 pp.

HOOVEN, OWENS, RENTSCHLER CO., *Hamilton, O.* Bulletin 104, Type H. S. high speed Corliss engines, 10 pp.; Bulletin 105, Series A, standard girder frame Hamilton Corliss engine, 8 pp.; Bulletin 106, Hamilton-Holzwarth flexible coupling, 8 pp.; Bulletin 107, Heavy duty Hamilton Corliss engines, 8 pp.; Bulletin 108, Hamilton-Corliss compound heavy duty engines, 12 pp.; Bulletin 110, Series B Hamilton Corliss engine, 8 pp.

JEFFREY MFG. CO., *Columbus, O.* Catalogue 69 B. Revolving, stone and gravel bell shaped, panel and tipple screens, 24 pp.; Bulletin 17, Electric mine locomotives, 68 pp.

LAMSON CONSOLIDATED STORE SERVICE CO., *Boston, Mass.* Small hand and power operated elevators, dumb-waiters and automatic conveyors, 24 pp.

MURRAY IRON WORKS CO., *Burlington, Ia.* Corliss engines, 80 pp.

NILES-BEMENT-POND CO., *New York.* LeBlond milling machines, 42 pp.

NORTH WESTERN EXPANDED METAL CO., *Chicago, Ill.* Expanded metal for sidewalks, culverts, slab bridges, 24 pp.

ONEIDA STEEL PULLEY CO., *Oneida, N. Y.* Catalogue of steel and wood pulleys, 48 pp.

PIERCE MOTOR CO., *Racine, Wis.* Pierce-Racine model K, 30 h.p. motor car, 16 pp.

PITTSBURGH FEED WATER HEATER CO., *Pittsburgh, Pa.* Feed water heater and purifier, 60 pp.

PRATT & WHITNEY CO., *Hartford, Conn.* Vertical surface grinder, 24 pp.

ROCKWELL FURNACE CO., *New York.* Bulletin G, Annealing, hardening, tempering furnaces, 8 pp.

SCHOEN-JACKSON CO., *Media, Pa.* Flexible metal tubing and connections for pressures up to 4000 pounds, 16 pp.

STEPHENS-ADAMSON MFG. CO., *Aurora, Ill.* Conveying and Transmission, January 1910, 24 pp.

STERLING ENGINE CO., *Buffalo, N. Y.* High grade marine engines for cruising work and speed boats, 32 pp.

STORRS MICA CO., *Owego, N. Y.* "Never-Break" mica chimneys and globes, 20 pp.

UNITED STATES MINERAL WOOL CO., *New York.* Mineral wool in car building and steam engineering 10 pp.

WARNER INSTRUMENT CO., *Beloit, Wis.* The Auto-Meter, speed indicator for automobiles and motor cars, 24 pp.

WHEELER CONDENSER AND ENGINEERING CO., *Carteret, N. J.* A radical improvement in jet condensers, 15 pp.

WILLIAMSON SUBMARINE CORPORATION, *Norfolk, Va.* Submarine Bulletin, December 1909, 4 pp.

UNITED ENGINEERING SOCIETY

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GIFT OF CARNEGIE STEEL COMPANY

DATA APPERTAINING TO LIGHT RAILS AND FASTENINGS, 1904.

POCKET COMPANION CONTAINING USEFUL IMFORMATION AND TABLES APPERTAINING TO THE USE OF STEEL. 1903.

SHAPES MANUFACTURED BY CARNEGIE STEEL COMPANY. 1903 and supplement.

STEEL MINE TIMBERS, DATA AND TABLES FOR THE USE OF MINING ENGINEERS, 46 pp.

STEEL SHEET PILING, 16 pp.

SCHOEN STEEL WHEELS. No. 1, 46 pp.

SCHOEN STEEL WHEELS, DESIGNS AND SPECIFICATIONS, 46 pp.

CARNEGIE SPECIAL WELDING STEEL, CARNEGIE SPECIAL THREADING STEEL, 40 pp.

CARNEGIE STEEL CROSS TIE AND DUQUESNE RAIL JOINT, 61 pp.

STEEL SHEET PILING. Types of construction and examples of installation, 64 pp.

STEEL MINE TIMBERS. Types of construction and examples of installation, 30 pp.

EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 15th of the month. The list of men available is made up of members of the Society and these are on file, with the names of other good men not members of the Society, who are capable of filling responsible positions. Information will be sent upon application.

POSITIONS AVAILABLE

010 Assistant superintendent of factory manufacturing a line of small interchangeable parts in large quantities; man with technical training preferred. Must be experienced in shop management. Wanted May 1. Location, Philadelphia, Pa.

011 Wanted—Competent mechanical draftsman, preferably one who has had experience in coal mine equipment. Give full particulars, including salary required. Location, Birmingham, Ala.

012 Wanted—Thoroughly practical and energetic young man for experimental and testing department of large corporation. Must be technical graduate of three or four years standing. Principal work consists of engine and boiler testing, as well as all matters pertaining to power, exclusive of electric. Excellent chance for right man to become assistant.

013 Opening for three engineer-salesmen between twenty-five and thirty-five years of age, for selling gas and oil engines in and around New York City. Men of experience in selling are preferred. Applicant must of course be able to give the best of references.

014 Wanted—Ice-making and refrigerating machinery salesmen; experienced men preferred. Applicants should be between thirty and forty years of age.

MEN AVAILABLE

25 Technical graduate, Junior Member, several years' experience in engineering work and as sales engineer with manufacturers of internal combustion engines. Considerable traveling experience. Location of minor importance, opportunities all-important.

26 Member, at present superintendent in large machine shop, where he has been for several years, would like a change of locality; 19 years' experience in manufacture of steam engines, steam turbines, and machine tools. Capable of filling first-class position.

27 Technical graduate, experienced in varied lines of industry, has held executive positions of responsibility; desires to become associated in position of trust with good manufacturing concern, preferably located in the East or Middle West. Best of references.

28 Associate wishes position as general manager, assistant, sales manager or salesman. Good executive ability, twenty years' experience with machine-tool manufacturing company, and as appraiser and receiver.

29 Member having extensive executive and mechanical experience desires to secure a position in greater New York or vicinity as superintendent or factory manager. Light, medium or heavy lines; large experience in intricate automatic and precision mechanisms as well as modern manufacturing methods and systems.

30 Member, technical graduate; 15 years' experience in power plant equipment and rolling mill machinery with well-known firm, last five years in engineering sales work, desires responsible position in the commercial end of a metal trade business, or as branch manager on commission basis. Experience in this country and abroad.

31 Member, graduate mechanical engineer, 18 years' experience in the States, England and France, as chief draftsman, general superintendent, selling and buying engineer, desires responsible position. Good executive, specialty automatic, hydraulic and conveying machinery. Best references.

32 Graduate in mechanical engineering, Massachusetts Institute of Technology, with experience including shop, inspection and drafting work, desires position in engineer's office as assistant to superintendent, or similar position. Minimum salary expected at start, $900 per year.

33 Mechanical engineer, Associate Member; 8 years of expert work in the reduction of power costs in industrial plants. Present practice as consulting engineer in this capacity and showing large savings. Desires further connection with a limited number of manufacturing power-users, permanent position as advisory engineer with large concern operating a number of plants or commercial proposition with concern manufacturing power plant apparatus.

34 Member, with thorough business training; up-to-date factory manager; good executive and organizer; competent in manufacturing medium and light weight machinery; fully qualified to fill position of responsibility, desires a position.

35 Steam turbine designer with 5 years' experience in charge of experimental work, desires position with firm now building or intending to develop a line of steam turbines.

36 Mechanical engineer, technical graduate, 16 years' practical experience, familiar with hoisting, conveying and general mill machinery, several years experience in charge of work, desires engineering position.

37 Junior Member, graduate engineer, desires a position which will offer a future. Experienced in general manufacturing methods; at present employed as engineer and assistant to general manager of a modern plant embracing power house, pattern department, foundry, carpenter and machine shops. Salary $2000.

38 Junior, 1908, technical graduate, some knowledge of boilers, desires position testing or installing power plant apparatus.

39 Member with 15 years' experience in steam engineering and power plant equipment, drafting-room office and selling, also several years machine design; desires position with consulting engineer or in engineering work with industrial company. Location east of Pittsburg preferred.

40 Young man, ten years shop experience in one of the largest manufacturing and engineering concerns in New York, for the past five years estimating engineer in charge of contract-engineering work; technical graduate; desires position as purchasing engineer or in an engineering construction department. New England or Middle Atlantic States preferred. Can furnish the highest of references.

CHANGES IN MEMBERSHIP

CHANGES OF ADDRESS

ALGER, Harley C. (Junior, 1908), Mech. Engr., 45 E. 16th St., Chicago Heights, Ill.

BAENDER, Fred. Geo. (Junior, 1909), Mech. Engr., 310 E. 18th Ave., Spokane, Wash.

BEECHER, J. F. (Associate, 1908), Draftsman, Pa. Steel Co., and *for mail*, 523 N. Fourth St., Harrisburg, Pa.

CALEY, Charles J. (1906), Wks. Mgr., Peterboro Lock Mfg. Co., Ltd., and Oriental Hotel, Peterboro, Ont., Canada.

CHAMBERLAIN, George E. (1907), Pres., Lewell Mfg. Co., 1416 Michigan Ave., Chicago, and *for mail*, 102 S. Waiola Ave., La Grange, Ill.

CHESTER, C. P. (Associate, 1908), Cons. Engr., 512 Caples Bldg., El Paso, Texas.

COMSTOCK, Charles Warren (Associate, 1906), Pres., Comstock-Wellman Bronze Co., 6017 Superior Ave., and *for mail*, 8803 Euclid Ave., Cleveland, O.

COOKE, Thomas F. (Junior, 1904), Cons. Engr., Webb & Cooke, 338 Ellicott Sq., and *for mail*, 618 Delaware Ave., Buffalo, N. Y.

FULWEILER, John Edwin (Junior, 1908), United Gas Improvement Co., and *for mail*, 4335 Chestnut St., Philadelphia, Pa.

GUMP, Walter B. (Junior, 1902), Mech. Engr., 2510 Juliet St., Los Angeles, Cal.

INGALLS, Fred. D. B. (1909), Cons. Mech. Engr., Rosenblum Bldg., 106 E. Fayette St., Syracuse, N. Y.

JOHNSON, Paul F. (1905), Johnson Service Co., Milwaukee, Wis.

KEITH, Thomas M. (Junior, 1905), Robins Conveying Belt Co., 30 Church St., New York, N. Y.

LAIDLAW, Walter (1889), Manager, 1905–1908; Intl. Steam Pump Co., 115 Broadway, New York, N. Y.

LEWIS, Wm. Yorath (1902), Engr., 49 Queen Victoria St., London, E. C., England.

MacKENZIE, Donald (Junior, 1902), Swift & Co., Stock Yards Sta., Chicago, Ill.

MORRISON, Clarke J. (1909), 52 E. 19th St., New York, N. Y.

NEILER, Samuel Graham (1907), Cons. Engr. and Pres., Pierce, Richardson & Neiler, 1407–1411 Manhattan Bldg., Chicago, and Oak Park, Ill.

NIBECKER, Karl (Junior, 1908), Mech. Engr., Southwark Fdy. & Mch. Co., Fifth and Washington Ave., Philadelphia, and *for mail*, Glen Mills, Pa.

POTTS, S. Warren (1909), 628 W. 148th St., New York, N. Y.

SCHAKEL, Jacob Daniel (Associate, 1907), Otis Elev. Co., Northland Ave. and Girder St., Buffalo, N. Y.

SCHREUDER, Andrew M. (1898; 1909), Supt., Philadelphia Textile Mchy., Co., Hancock and Somerset Sts., Philadelphia, and *for mail*, 5351 Wayne Ave., Germantown, Philadelphia. Pa.

SCOTT, Walter G. (Junior, 1909), Allis-Chalmers Co., and *for mail*, University Club, West Allis, Wis.

SPENCER, Frank C. (Associate, 1908), Mech. and Constr. Engr., 5258 Indiana St., Chicago, Ill.

STARBUCK, George F. (Junior, 1901), Draftsman, Boston Elev. Ry., Boston, and *for mail*, Waltham, Mass.

SMITH, S. H. (Associate, 1907), Supt., North Melbourne Elec. Tramways & Ltg. Co., Ltd., Mt. Alexander Rd., and Clydehall, Harding and East Sts., Ascot Vale, Melbourne, Australia.

TAYLOR, Cecil Hamelin (Associate, 1908), Ch. Engr., Hudson Motor Car Co., and Pasadena, Detroit, Mich.

TREGELLES, Henry (1888), Bartolome Mitre 544, Buenos Aires, and Hurlingham and Pacifico, Buenos Aires, Argentine Repub., South America.

VON AMMON, Siegfried (1904; 1905), Fontella, Va.

WADDELL, Charles E. (1903; 1907), Cons. Engr., 78 Patton Ave., Asheville, N. C.

WALKER, Gilbert S. (1904), Isthmian Canal Com., Mills Bldg. Annex, Washington, D. C.

WHEELER, Earl (Junior, 1907), Elec. and Mech. Engr., Elec. Speedometer & Dynamometer Mfg. Co., 1317 New York Ave., and *for mail*, The Benedict, 1810 I St., N. W., Washington, D. C.

WHEELER, Wm. Trimble (1905), 286 Greenwich St., and 340 W. 21st. St., New York, N. Y.

NEW MEMBERS

ARBOGAST, Victor R. (1909), Wks. Engr. and Supt., Natl. Radiator Gesellschaft, Schoenebeck Elbe, Germany.

BACON, John Lord (1899; 1909), Engr. and Supt. of Constr., R. P. Shields & Son, 605 Scripps Bldg., and *for mail*, 3576 A St., San Diego, Cal.

BLUM, Arthur N. (1909), Asst. Mgr., Sormovo Engrg. Wks., Nijni Novgorod, Russia.

BORNHOLT, Oscar Charles (1904; 1909), Mech. Engr., Ford Motor Co., Piquette Ave. and Beaubien St., and *for mail*, 50 Philadelphia Ave., Detroit, Mich.

DAY, Leonard A. (1909), First Asst. Mech. Engr., St. Louis Water Dept., and *for mail*, 4015 Greer Ave., St. Louis, Mo.

DIMAN, W. G. (1909), Senior Engr. Officer, U. S. S. Mayflower, Navy Dept., Washington, D. C.

FERRIER, Joseph J. (Junior, 1909), So. Pacific Co., 1110 Flood Bldg., San Francisco, Cal.

FRANK, Edwin (Junior, 1909), Designer, Maffei-Schwartzkopff Wks., G. m. b. H., and *for mail*, Kaiser Wilhelmstr., 10, Zeuthen i M, Germany.

HERRIMAN, Victor D. (Junior, 1909), Engr., Intl. Steam Pump Co., 115 Broadway, New York, and *for mail*, 167 Quincy St., Brooklyn, N. Y.

HORTON, Charles M. (Junior, 1909), Secy., Ford Refrig. Air-Machine Co., and *for mail*, 101 W. 101st St., New York, N. Y.

KNEELAND, Frank H. (Junior, 1909), Mech. Engr., U. S. Coal & Coke Co., Gary, W. Va.

PARSONS, Edmund S. (Junior, 1909), Mech. Engr., Remington Typewriter Wks., and *for mail*, 56 West St., Ilion, N. Y.

POLHEMUS, Louis Edward (Junior, 1909), Asst. M.M., Mexican Light & Power Co., Necaxa (Estado de Puebla), Mexico.

POOLE, Cecil P. (1909), Joint Editor, Power and The Engineer, 505 Pearl St., New York, N. Y., and South Orange, N. J.

RANSOM, T. Wells (1909), Cons. Mech. Engr., Board of Public Wks., San Francisco, Cal.

SOVERHILL, Harvey A. (1909), Supt., Root & Van Dervoort Engrg. Co., East Moline, and 623 23d St., Moline, Ill.

TORRANCE, Chas. Everett (Junior, 1909), Instr., Sibley College, and *for mail*, 638 Stewart Ave., Ithaca, N. Y.

DEATHS

BALDWIN, Stephen W.

BATCHELOR, Charles.

SANGUINETTI, Percy A.

GAS POWER SECTION

CHANGES OF ADDRESS

BAENDER, Fred Geo. (1909), Mem. Am.Soc.M.E.
FISKE, Geo. Wallace (Affiliate, 1909), 610 W. 10th St., Topeka, Kan.
MYERS, Theodore B. (Affiliate, 1909), Woodcliff-on-Hudson, N. J.
PARKER, Lewis C. (Affiliate, 1908), present address unknown.

NEW MEMBERS

COLLINS, Harold W. T. (Affiliate, 1910), Designer, Lodge & Shipley Mch. Tool Co., Cincinnati, and *for mail*, 2242 Cameron Ave., Norwood, O.
CRAIG, James (1910), Mem. Am.Soc.M.E.
DORSEY, Howard Alex. (Affiliate, 1910), Instr. Mech. Engrg., Univ. of Cincinnati, Cincinnati, O.
FERRIER, Joseph J. (1910), Mem. Am.Soc.M.E.
GARDNER, F. M. (Affiliate, 1910), Engr. and Salesman, Fairbanks, Morse & Co., and *for mail*, 137 W. Fourth St., Cincinnati, O.
GRIFFITHS, Leonard L. (1910), Mem. Am.Soc.M.E.
JEWETT, Arthur C. (1910), Mem. Am.Soc.M.E.
MANGELSDORFF, Max F. (Affiliate, 1910), 115 Nassau St., New York, N. Y.
POOLE, Cecil P. (1909), Mem.Am.Soc.M.E.
READ, Carleton A. (1910), Mem. Am.Soc.M.E.
ROE, Joseph W. (1910), Mem. Am.Soc.M.E.
SCHWENKER, Robert Frederick (Affiliate, 1910), Mech. Engr., 3913 Regent Ave., Norwood, O.
TORRANCE, Charles E. (1910), Mem. Am.Soc.M.E.
WHITTLESEY, James Thomas (1910), Mem. Am. Soc. M. E.

STUDENT BRANCHES

CHANGES OF ADDRESS

DUNSHEATH, L. M. (Student, 1909), 105 E. Healey St., Champaign, Ill.
GROSSBERG, Arthur S. (Student, 1909), Mineral Point Zinc Co., Depue, Ill.
HERBERT, E. H. (Student, 1909), Doak Gas Eng. Co., 7–9 First St., San Francisco, Cal.
KOWALEWSKI, A. J. (Student, 1910), 582 Main Bldg., State College, Pa.
MANSFIELD, W. M. (Student, 1909), 2924 Mt. Vernon Ave., Milwaukee, Wis.
ROMIG, F. G. (Student, 1910), 601 S. Wright St., Champaign, Ill.
TIFFT, R. H. (Student, 1909), 65 Park Avenue, New York, N. Y.

NEW MEMBERS

COLUMBIA UNIVERSITY

BAUM, A. L. (Student, 1910), 252 W. 128th St., New York, N. Y.
BLUMENFELD, Ralph (Student, 1910), 508 W. 114th St., New York, N. Y.
BRETTELL, C. (Student, 1910), 29 Meadow Lane, New Rochelle, N. Y.
FRAMBACH, F. S. (Student, 1910), 430 W. 119th St., New York, N. Y.
GATELY, W. A. (Student, 1910), 125 E. 54th St., New York, N. Y.
GUITERAS, J. G. (Student, 1910), 1 Livingston Ave., Yonkers, N. Y.
HAYNES, J. L. (Student, 1910), 3216 Glenwood Rd., Brooklyn, N. Y.
JAROS, A. L. (Student, 1910), 542 W. 112th St., New York, N. Y.
KATZ, E. J. (Student, 1910), 249 E. 68th St., New York, N. Y.
KIRSCHBERG, M. (Student, 1910), 25 W. 123d St., New York, N. Y.
LACY, F. T. (Student, 1910), 411 W. 115th St., New York, N. Y.
LORD, J. W. (Student, 1910), 163 E. 71st St., New York, N. Y.

CORNELL UNIVERSITY

BENBOW, J. R. (Student, 1910), 210 Linden Ave., Ithaca, N. Y.
HAM, C. W. (Student, 1910), 126 E. Seneca St., Ithaca, N. Y.
PIMPER, T. F. (Student, 1910), 427 E. Seneca St., Ithaca, N. Y.
ROBINSON, G. E. (Student, 1910), 208 Williams St., Ithaca, N. Y.
STURGIS, R. F. (Student, 1910), 110 Sage Pl., Ithaca, N. Y.

BROOKLYN POLYTECHNIC INSTITUTE

BARRETT, S. A. K. (Student, 1910), 114 Pierrepont St., Brooklyn, N. Y.
ERICSON, E. O. (Student, 1910), Helmetta, Middlesex Co., N. J.
GRIFFIN, E. F. (Student, 1910), Box 417, Oyster Bay, L. I., N. Y.

PENNSYLVANIA STATE COLLEGE

FORKER, Geo. M. (Student, 1910), 203 McAllister Hall, State College, Pa.
KAIER, John B. (Student, 1910), 283 Lehigh St., Wilkes-Barre, Pa.
MARSH, Karl H. (Student, 1910), The Lincoln, Youngstown, O.
PERHAM, Dean E. (Student, 1910), 512 Main Bldg., State College, Pa.
WESTERMAN, John H. (Student, 1910), Theta Psi House, State College, Pa.

STATE AGRICULTURAL COLLEGE OF OREGON

GRAF, Samuel Herman (Student, 1910), State Agri. College of Oregon, Corvallis, Oregon.
HASKELL, William Dexter (Student, 1910), State Agri. College of Oregon, Corvallis, Oregon.
LINES, J. Donald (Student, 1910), State Agri. College of Oregon, Corvallis, Oregon.

STEVENS INSTITUTE OF TECHNOLOGY

BRUCE, A. C. (Student, 1910), 934 Bloomfield St., Hoboken, N. J.
MONESTEL, Alberto A. (Student, 1910), 518 Hudson St., Hoboken, N. J.
SCHOCH, Floyd W. (Student, 1910), 507 River St., Hoboken, N. J.

UNIVERSITY OF ILLINOIS

BANNISTER, B. (Student, 1910), 412 E. Green St., Champaign, Ill.
HASBERG, Will (Student, 1910), 307 E. Green St., Champaign, Ill.
MURDUCK (Student, 1910), 705 W. Hills St., Champaign, Ill.

UNIVERSITY OF KANSAS

FAIRCHILD, F. P. (Student, 1910), 946 Ohio St., Lawrence, Kan.

COMING MEETINGS

MARCH–APRIL

Advance notices of annual and semi-annual meetings of engineering socleties are regularly published under this heading and secretaries or members of societies whose meetings are of interest to engineers are invited to send such notices for publication. They should be in the editor's hands by the 18th of the month preceding the meeting. When the titles of papers read at monthly meetings are furnished they will also be published.

AMERICAN ASSOCIATION OF RAILROAD SUPERINTENDENTS
March 18, Chicago. Secy., O. G. Fetter.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
March 11, with Am. Soc. M. E., 29 W. 39th St., New York. Papers: Electric Mine Hoists with Illgner Motor Generator Set, R. R. Seeber; Comparison of Electric and Compressed Air Drives for Mine Hoists, W. Sykes. March 30-April 1, Selwyn Hotel, Charlotte, N. C. Papers: Economics of Hydroelectric Plants, W. S. Lee, Mem. Am. Soc. M. E., Electric Drive in Textile Mills, A. Milmow; Gas Engines in City Railway and Light Service, E. D. Latta, Jr.; Protecting Insulators from Lightning and Power Arc Effects On Lines of the Niagara and Lockport Power Co., L. C. Nicholson. Secy., R. W. Pope. April 21, San Francisco, Cal. Papers : Economics of a Generator Power System, P. M. Downing; Hydroelectric Developments and Irrigation, J. C. Hays.

AMERICAN INSTITUTE OF MINING ENGINEERS
March 1-5, Spring Meeting, Hotel Schenley, Pittsburg, Pa. Secy., R. W. Raymond, 29 W. 39th St., New York.

AMERICAN MATHEMATICAL SOCIETY
April 30, Columbia University, 156 W. 116th St., New York. Secy., F. N. Cole.

AMERICAN RAILWAY ENGINEERING ASSOCIATION
March 14-17, Chicago. Secy., E. H. Field, Monadnock Bldg.

AMERICAN RAILWAY ENGINEERING AND MAINTENANCE OF WAY ASSOCIATION
March 15–17, annual convention, Chicago. Secy., E. H. Fritch, 962 Monadnock Blk.

AMERICAN SOCIETY OF CIVIL ENGINEERS
March 2, 1910, 220 W. 57th St., New York. Paper: The Improved Water and Sewage Works of Columbus, O., J. H. Gregory. Secy., C. W. Hunt.

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
March 8, 29 W. 39th St., New York. March 11, Auditorium Edison Electric Illuminating Co. of Boston, Boston, Mass. May 31-June 3, Spring Meeting, Atlantic City, N. J. July 26-29, meeting in Birmingham, England. Secy., Calvin W. Rice, 29 W. 39th St., New York.

AMERICAN SUPPLY AND MACHINERY MANUFACTURERS ASSOCIATION
SOUTHERN SUPPLY AND MACHINERY DEALERS ASSOCIATION
April 5–7, Seminole Hotel, Jacksonville, Fla.

AMERICAN WATERWORKS ASSOCIATION
April 26-30, annual convention, New Orleans, La. Secy., J. M. Diven, 14 George St., Charlestown, S. C.

BROOKLYN ENGINEERS CLUB
March 3, monthly meeting, 117 Remsen St. Paper: The Making of a Marble Quarry, by T. B. Hamilton. Secy., Joseph Strachan.

BOSTON SOCIETY OF ARCHITECTS
March 1, regular meeting with reports, Parker House. Secy., E. J. Lewis, Jr.

BOSTON SOCIETY OF CIVIL ENGINEERS
March 2, annual meeting, Boston City Club, 7.30 p.m. Paper: Ventilation of Subways, G. A. Soper.

CANADIAN FORESTRY ASSOCIATION
March 10-11, Fredericton, N. B. Secy., Jas. Lawler, 11 Queen's Park, Toronto, Ont.

CANADIAN FREIGHT ASSOCIATION
April 14, annual meeting, Montreal. Secy., T. Marshall, Toronto, Ont.

CANADIAN MINING INSTITUTE
March 2-4, annual meeting, Toronto, Ont. Secy., H. Mortimer-Lamb, Windsor Hotel, Montreal.

ENGINEERS SOCIETY OF WESTERN PENNSYLVANIA
March 1, Fulton Bldg., Pittsburg, 8 p.m. Discussion on Present-Day Needs in Structural Materials. Secy., E. K. Hiles.

FLORIDA ELECRTIC LIGHT AND POWER ASSOCIATION
April 12, annual meeting, Tampa. Secy., G. I. Doig, Gainesville.

IOWA ASSOCIATION CEMENT USERS
March 9-11, Cedar Rapids. Secy., Ira Williams, Ames.

IOWA ELECTRICAL ASSOCIATION
April 20-21, annual convention. Secy., W. N. Keiser, Des Moines.

IOWA STREET AND INTERURBAN RAILWAY ASSOCIATION
April, Sioux City. Secy., L. D. Mathes.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, Student Branch, Am. Soc. M. E.
March 8, annual meeting, Boston. Secy., A. P. Truette.

MINNESOTA ELECTRIC ASSOCIATION
March, St. Paul. Secy., B. W. Cowperthwait.

MISSOURI ELECTRIC, GAS, RAILWAY AND WATERWORKS ASSOCIATION.
April 14-16, Jefferson City. Secy., C. L. Clary, Sikeston.

MODERN SCIENCE CLUB
March 29, annual dinner; April 12, annual election, 125 S. Elliott Pl., Brooklyn, N. Y. Secy., J. A. Donnelly.

NATIONAL ASSOCIATION OF COTTON MANUFACTURERS
April 27–28, semi-annual meeting. Secy., Dr. C. J. H. Woodbury, Mem. Am. Soc. M. E., Box 3672, Boston.

NATIONAL MACHINE TOOL-BUILDERS ASSOCIATION

May, Spring Convention, Rochester, N. Y. Secy., C. Hildreth, Worcester, Mass.

NEW ENGLAND RAILROAD CLUB

March 8, annual meeting, Copley Square Hotel, Boston. Subject for Discussion: M. C. B. Rules of Interchange. Secy,. G. H. Frazier, 10 Oliver St.

NEW ENGLAND STREET RAILWAY CLUB

March 24, annual meeting, Boston, Mass. Secy., J. J. Lane, 12 Pearl St.

NEW ENGLAND WATERWORKS ASSOCIATION

April 13, special meeting, Hartford, Conn. June, Providence, R. I. September 14-16, annual convention, Rochester, N. Y. Secy., Willard Kent, Narrangansett Pier, R. I.

PROVIDENCE ASSOCIATION OF MECHANICAL ENGINEERS

March 22, April 26; West Hall. R. I. School of Design, 8 p. m. Papers: The Fitchburg Plan of Coöperative Industrial Education, W. B. Hunter, M. A. Coolidge; Oxy-Acetylene Welding and Cutting, Henry Cave. Secy., Prof. T. M. Phetteplace, Mem. Am. Soc. M. E., 48 Snow St.

RAILWAY SIGNAL ASSOCIATION

March 14, Chicago. Secy., C. C. Rosenberg, Bethlehem, Pa.

SOCIETY OF CHEMICAL INDUSTRY

April 1, annual meeting, New England section. Secy., Alan Claflin, 88 Broad St., Boston, Mass.

STEVENS ENGINEERING SOCIETY

March 1, 8, 15, 22, 31, Hoboken, N. J. Papers: Automobiles, J. F. O'Rourke, H. F. Cuntz; Arts and Industries of the Orient, W. J. Hammer, C. R. Richards; on the Gyrostat and its Applications, G. V. Wendell. Secy., R. H. Upson.

MEETINGS IN THE ENGINEERING SOCIETIES BUILDING

Date	Society	Secretary	Time
March			
2	Wireless Institute	S. L. Williams	7.30
3	Blue Room Engineering Society	W. D. Sprague	8.00
5	Amer. Soc. Hungarian Engineers and Architects	Z. deNémeth	8.30
8	The American Society of Mechanical Engineers	Calvin W. Rice	8.15
10	Illuminating Engineering Society	P. S. Millar	8.00
11	American Institute of Electrical Engineers	R. W. Pope	8.00
15	New York Telephone Society	T. H. Lawrence	8.00
18	New York Railroad Club	H. D. Vought	8.15
23	Municipal Engineers of the City of New York	C. D. Pollock	8.15
April			
2	Amer. Soc. Hungarian Engineers and Architects	Z. deNemet	8.30
6	Wireless Institute	S. L. Williams	7.30
7	Blue Room Engineering Society	W. D. Sprague	8.00
8	American Institute of Electrical Engineers	R. W. Pope	8.00
12	The American Society of Mechanical Engineers	Calvin W. Rice	8.15
14	Illuminating Engineering Society	P. S. Millar	8.00

Date	Society	Secretary	Time
April			
15	New York Railroad Club	H. D. Vought	8.15
19	New York Telephone Society	T. H. Lawrence	8.00
27	Municipal Engineers of the City of New York	C. D. Pollock	8.15

OFFICERS AND COUNCIL

PRESIDENT

GEORGE WESTINGHOUSE ..... Pittsburg, Pa.

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Terms expire at Annual Meeting of 1910

CHARLES WHITING BAKER ..... New York
W. F. M. GOSS ..... Urbana, Ill.
E. D. MEIER ..... New York

Terms expire at Annual Meeting of 1911

PAST PRESIDENTS

Members of the Council for 1910

JOHN R. FREEMAN ..... Providenee, R. I.
FREDERICK W. TAYLOR ..... Philadelphia, Pa.
F. R. HUTTON ..... New York
M. L. HOLMAN ..... St. Louis, Mo.
JESSE M. SMITH ..... New York

MANAGERS

WM. L. ABBOTT ..... Chicago, Ill.
ALEX. C. HUMPHREYS ..... New York
HENRY G. STOTT ..... New York

Terms expire at Annual Meeting of 1910

H. L. GANTT ..... Pawtucket, R. I.
I. E. MOULTROP ..... Boston, Mass.
W. J. SANDO ..... Milwaukee, Wis.

Terms expire at Annual Meeting of 1911

J. SELLERS BANCROFT ..... Philadelphia, Pa.
JAMES HARTNESS ..... Springfield, Vt.
H. G. REIST ..... Schenectady, N. Y.

Terms expire at Annual Meeting of 1912

TREASURER

WILLIAM H. WILEY ..... New York

CHAIRMAN OF THE FINANCE COMMITTEE

ARTHUR M. WAITT ..... New York

HONORARY SECRETARY

F. R. HUTTON ..... New York

SECRETARY

CALVIN W. RICE ..... 29 West 39th Street, New York

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CHAS. WHITING BAKER, *Vice-Chairman*
F. M. WHYTE
F. R. HUTTON
H. L. GANTT

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FINANCE

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EDWARD F. SCHNUCK (1)
ROBERT M. DIXON (3), *Vice-Chairman*
GEO. J. ROBERTS (2
WALDO H. MARSHALL (4)

HOUSE

WILLIAM CARTER DICKERMAN (1) *Chairman*
BERNARD V. SWENSON (2)
FRANCIS BLOSSOM (3)
EDWARD VAN WINKLE (4)
H. R. COBLEIGH (5)

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JOHN W. LIEB, JR. (3), *Chairman*
AMBROSE SWASEY (1)
LEONARD WALDO (2)
CHAS. L. CLARKE (4)
ALFRED NOBLE (5)

MEETINGS

WILLIS E. HALL (5), *Chairman*
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L. R. POMEROY (2)
CHAS. E. LUCKE (3)
H. DE B. PARSONS (4)

MEMBERSHIP

CHARLES R. RICHARDS (1) *Chairman*
FRANCIS H. STILLMAN (2)
GEORGE J. FORAN (3)
HOSEA WEBSTER (4)
THEO. STEBBINS (5)

PUBLICATION

D. S. JACOBUS (1) *Chairman*
H. F. J. PORTER (2)
H. W. SPANGLER (3)
GEO. I. ROCKWOOD (4)
GEO. M. BASFORD (5)

RESEARCH

W. F. M. GOSS (4), *Chairman*
R. C. CARPENTER (1)
R. H. RICE (2)
RALPH D. MERSHON (3)
JAS. CHRISTIE (5)

NOTE—Numbers in parentheses indicate number of years the member is yet to serve.

SPECIAL COMMITTEES

1910

On a Standard Tonnage Basis for Refrigeration

D. S. JACOBUS — G. T. VOORHEES
A. P. TRAUTWEIN — PHILIP DE C. BALL
E. F. MILLER

On Society History

JOHN E. SWEET — H. H. SUPLEE
CHAS. WALLACE HUNT

On Constitution and By-Laws

CHAS. WALLACE HUNT, *Chairman* — F. R. HUTTON
G. M. BASFORD — D. S. JACOBUS
JESSE M. SMITH

On Conservation of Natural Resources

GEO. F. SWAIN, *Chairman* — L. D. BURLINGAME
CHARLES WHITING BAKER — M. L. HOLMAN
CALVIN W. RICE

On International Standard for Pipe Threads

E. M. HERR, *Chairman* — GEO. M. BOND
WILLIAM J. BALDWIN — STANLEY G. FLAGG, JR.

On Standards for Involute Gears

WILFRED LEWIS, *Chairman* — E. R. FELLOWS
HUGO BILGRAM — C. R. GABRIEL
GAETANO LANZA

On Power Tests

D. S. JACOBUS, *Chairman* — L. P. BRECKENRIDGE — EDWARD F. MILLER
EDWARD T. ADAMS — WILLIAM KENT — ARTHUR WEST
GEORGE H. BARRUS — CHARLES E. LUCKE — ALBERT C. WOOD

On Student Branches

F. R. HUTTON, HONORARY SECRETARY

On Meetings of the Society in Boston

IRA N. HOLLIS, *Chairman* — I. E. MOULTROP, *Secretary*
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